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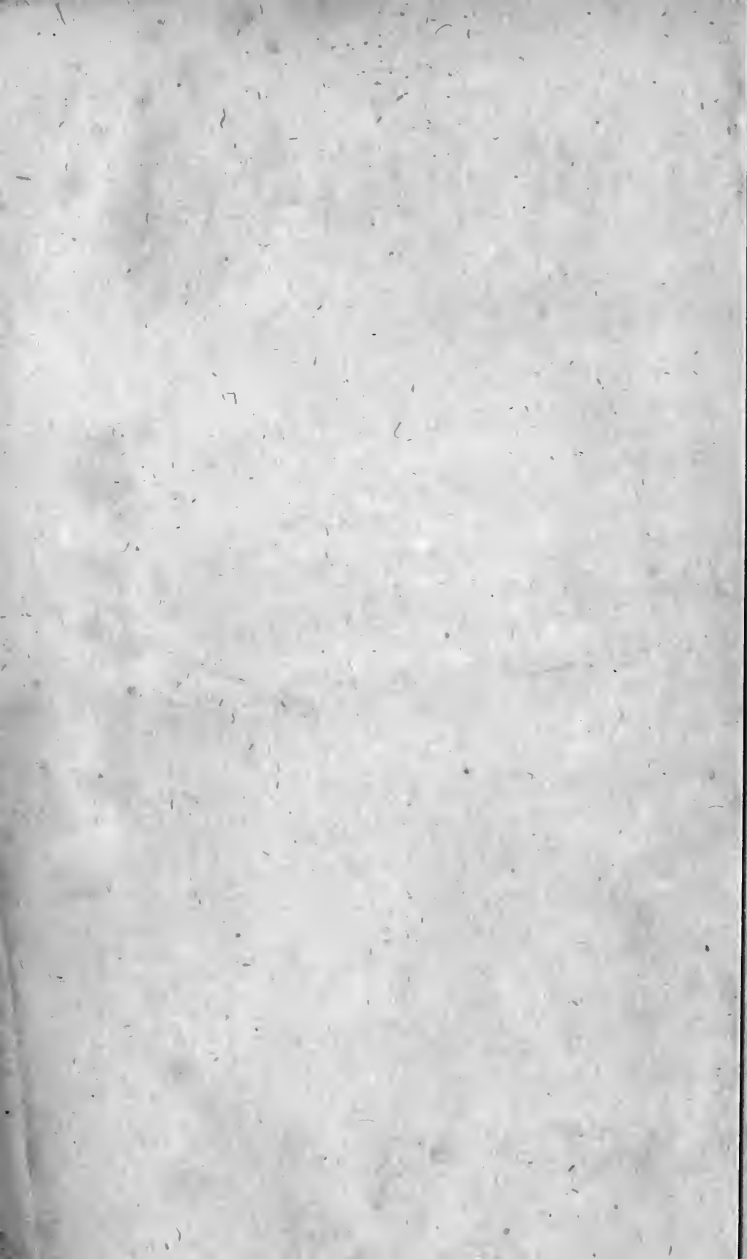
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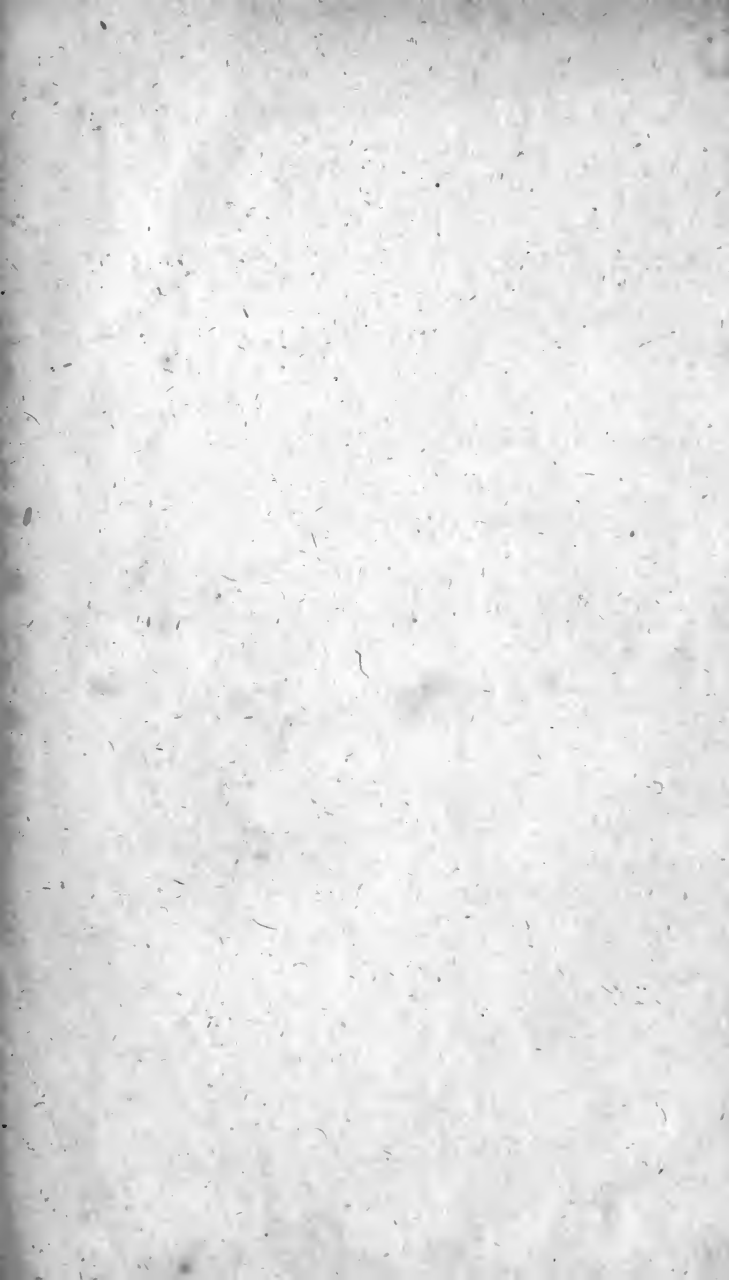
AN
ACCOUNT
OF
Animal Secretion,
The Quantity of Blood
In the Humane Body,

Wilhol And *Gibbs*

Muscular Motion.

By *James Keill*, M. D.

*Profecto verisimile est, & Hippocratem & Erasi-
stratum, & quicunque alii, non contenti Febres
& Ulcera agitare, rerum quoque naturam ex ali-
qua parte scrutati sint, non ideo quidem Medi-
cos fuisse, verum ideo quoque majores Medicos
exstitisse.* Celf. *in* Præf.

LONDON,

Printed for GEORGE STRAHAN at the *Gol-
den Ball* against the *Royal Exchange.*
1708.

THE

PREFACE.

Difeafes being purely Difor-
ders of the Animal Oecono-
my, whatfoever can add
any new Light to our Knowledge of
this, muft neceffarily clear the Nature
of thofe, eftablifh the Practice of Phy-
fick upon a furer Foundation, and en-
able Phyficians to make truer and more
certain Judgments in moft Cafes.

The Animal Body is now known
to be a pure Machine, and many of
its Actions and Motions are demon-
ftrated to be the neceffary Confequences
of its Structure. The Manner of Vi-
fion is fhown in Opticks. Borelli
has given us the Mechanifm of the
Bones and Mufcles for the moving of

the

the *Joints*. And *since the Discovery of the Circulation of the Blood by the famous Dr.* Harvey, *many useful Propositions concerning its Motion and Velocity have been determined by* Bellini. *Dr.* Pitcairne *has explained the mechanical Structure of the Lungs, shewn us the reason of the different Passages of the Blood; thro' the Heart of the Fœtus, the necessity of breathing after Birth, and how the ante-natalitial Ducts are stopp'd by breathing: He has likewise demonstratively explain'd the Symptomes of the Diseases of the Eyes, and demonstrated the circular Figure of the Orifices of the Glands. Dr.* Freind *has wrote in a mechanical way upon the* Menses; *Dr.* Cheyne *upon Fevers; and Dr.* Mead *of Poisons, and all of them have handled these Subjects more rationally than ever any did before them. In the following-*

*following Sheets is contained a Calcu-
lation of the Force of the Air upon the
Blood in Breathing, of the Quantity
of Blood in the Human Body, of its
absolute Velocity in the* Aorta. *The
use of the Spleen and* Vena Porta *is
now no longer a Mystery; and many*
Phœnomena *of the Animal Body
which the Ages past thought inexpli-
cable, have now by several been made
the Subjects of Geometrical Demon-
stration. That many Things still re-
main undiscovered, is not, that of
their own Nature they are less capable
of Demonstration; but that the Data
are not sufficient, we are not yet fully
apprised of all the Circumstances,
which conduce to produce such Phœ-
nomena. If some things which to
former Ages have appeared unaccount-
able, are now as clear and demonstra-
ble as the Pressure of the Air, why
should we not hope for a Discovery*

of the Things that are still hid from
us ? If we endeavour after them,
there is all the reason in the World to
believe we shall have Success, if we
consider the Progress that has already
been made, notwithstanding the me-
chanical Philosophy as applied to Phy-
sick is still in its Infancy.

Now since the Animal Body is a
pure Machine, and all its Actions
from which Life and Health do flow
are the necessary Consequences of its
Oeconomy; must not all the Symptomes
of Diseases be likewise the necessary
Consequences of the Alteration of this
Oeconomy ? And doe they not as ne-
cessarily flow from this Change, as the
Actions by which Life and Health
are continued did flow from the Oe-
conomy before the Change. If a Pen-
dulum of such a length makes a Clock
to goe exactly true ; does not the Al-
teration of the Pendulum as necessarily
                                    cause

cause it to go too fast or too slow; and when all the rest of the Movement is known to be in good order, does not the quick or slow Motion of the Clock, as necessarily show the Fault of the Pendulum? It is the same thing in the Animal Body, for the same reasoning holds good in all sort of Machines, whose Motions are the necessary Consequences of their Structures: nor is the Case in the least altered, that we have a Principle within us, not subject to the Laws of Motion; for our Souls are not at all conscious of the inward Motions of the Body upon which Life and Health depend, and tho' it do's sometimes influence our Health, yet the Irregularities it produces in the Oeconomy are to be rectified the same way as if they had proceeded from other Causes. Therefore it demonstratively follows that the greater our Knowledge of the Animal

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Oeconomy is, the better the Nature of Diseases must be known.

It must indeed be confessed that this Method of improving the Art of Physick is full of Difficulty, but the Nature of things cannot be altered; if it is to be improved, it must be by a Knowledge in the Animal Oeconomy, there being no other Method but what does really and in effect depend upon that.

Some do pretend that the Art of curing Diseases, is only to be promoted by Experiments, by observing what Things are hurtful, what beneficial in Diseases, that the Study of Nature and the Knowledge of the Body is altogether superfluous, and of as little use, as it would be to a Sailor to know the Reason of the Tides, or how to explain the Phænomena of the Loadstone. But if we consider the Number of Diseases, their different

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rent Species, different Appearances according to the almost infinite Variety of Constitutions of our Bodies, and the Air in which we live. If we reflect likewise on their various Complications, on the infinite Variety of Medicines, and the critical Times of using sometimes one and sometimes another, we may as well expect that a blind Man should shoot flying, or one that is deaf tune an Organ, as that any one without the Knowledge of the Animal Oeconomy should ever find out a Remedy for any one Distemper. The Art of curing did indeed at first rise from Experiments, and it cannot be denyed that several good Remedies have been found out by chance, or rather by Divine appointment, as without doubt the Use of the Bark was by the Indians; whom we may reasonably suppose to have been ignorant of the Animal Oeconomy, but

no Man can think this a good Method for improving of any Science : If indeed Experiments are directed, by a Knowledge in the Animal Oeconomy, something may be hoped for from such a Method, and the greater the Skill is by which the Experiments are directed, the greater will be the Probability of Success; because by that we can aim more directly and certainly at the Irregularities of the Oeconomy, and he that knows the Disease is more likely to cure than he that is wandring and dubious in his Mind, and uncertain what it is he ought to aim at. If he hits the Mark it is owing more to mere chance, than any good Skill. Experiments are the only Foundation upon which by a just reasoning we come at the Knowledge of any Phænomenon of Nature. Thus only Anatomical Experiments, and Observations
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ons upon the Structure of the Parts, Nature of the Blood, and Secretions, can enable us to understand the Phænomena of the Animal Body; without them the raising of Theories and Hypotheses is but building of Castles in the Air. The Theory indeed of any Art, which has already arrived at its highest Perfection, and which has all its Circumstances known, may perhaps be of as little use, as that of the Tides and Loadstone would be for sailing in the Channel : But either of these might be of great use to a Sailor taken out of his Knowledge to an unknown Part of the World. Physick has not as yet arrived at its greatest Perfection in the curing of any one Disease, we are still ignorant of more than we know, and the Circumstances of Diseases are infinitely various, and no general Rules whatsoever can be applied to

parti-

particular Cafes, without the Know-
ledge of the reafon of the Rule, that
is, without underftanding the Ani-
mal Oeconomy, upon which all Rules
of Phyfick are built.

But the Method of curing Difeafes,
by drawing Indications from the evi-
dent and conjunct Caufes, has been al-
ways moft approved by the beft and
Generality of Phyficians. The Know-
ledge of thefe Caufes is not to be at-
tained by reafon, but by a clofe and
affiduous Obfervation of all the Ap-
pearances in the feveral Stages of a
Diftemper. The firft that excelled in
this Knowledge was the Divine Hip-
pocrates, *whofe Delineations of*
Difeafes are truly charming. In
them one may difcern a wonderful At-
tention to all even the minuteft Opera-
tions of Nature, which produced a fur-
prizing Sagacity in judging of fu-
ture Events. In this Method feve-
ral.

*ral of the Ancients have followed him,
but none ever came so near to him, as
the deservedly renowned Dr. Syden-
ham, and Dr. Morton, whose Hi-
stories of Diseases, for a full, exact
and nice Enumeration, and Descri-
ption of evident Causes, Signs and
Symptomes, for a judicious distin-
guishing of the several Species of the
same Diseases, and for just Progno-
sticks founded upon a careful Obser-
vation of the common Effects of such
and such Apearances, have sur-
passed all Histories of the Modern
Physicians.*

*This is the Knowledge which added
to that of the Animal Oeconomy can
only make a Physician, one skilled in
Geometry may as well pretend to be
a good Astronomer, without knowing
the Motions and Revolutions of the
Heavenly Bodies, as a Philosopher,
or one skilled in the Animal Oeconomy,*

to be a Physician without the exact Knowledge of the Histories of Diseases. And as one ignorant of Geometry can make but a wretched Astronomer, so he can make no better a Physician that has not laid a good Foundation of the Animal Oeconomy. If we consider the Animal Body as a Machine, its Diseases, and all their Symptomes are only the irregular Motions of the Machine. Now suppose a Man ignorant of the Structure of a Clock or Watch, it is impossible he should ever be able to put it in right Order, tho' he had never so exact an History of its irregular Motions. So a Physician ignorant of the Animal Oeconomy, is ignorant of the Structure of the Machine he undertakes to regulate, and the best and exactest Histories of Diseases can never suggest to him any Indication of Cure. It is therefore the Animal

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mal Oeconomy which alone can enable us by reasoning upon the Causes, Signs and Symptomes of Diseases, to find out their Natures, and to deduce true and just Indications of Cure.

If we examine the Method of curing any Distemper we shall find what I have said to be true. For Instance, do not all the Symptomes of the Jaundice show us that the Liver is obstructed? And do we not deduce this Obstruction by our Knowledge of the Animal Oeconomy? And does not this Obstruction indicate, Bleeding, Vomiting, Purging and Deobstruent Medicines, which are used in curing of this Disease? If we know the Nature of the Humour which causes the Obstruction, perhaps Remedies might be found to cure such Jaundice as are now found to be incurable: For different Substances require different Resolvents, as every one

that

that is acquainted in Pharmacy and
Chymiſtry knows. From the Symptomes
of the Jaundice we juſtly draw the
Indication for giving deobſtruent Me-
dicines, but what are the moſt pro-
per Medicines of this kind, we know
not; becauſe we are ignorant of the
Nature of the Obſtruction. Our In-
dications therefore are true and juſt,
ſo far as our Knowledge of the Ani-
mal Oeconomy reaches; but where
that leaves us we only grope in the
dark, and find out Remedies by
Chance.

But this will be ſtill more evident
if we conſider, there is no Diſeaſe,
better known, or which has its moſt
minute Circumſtances better deſcribed
than a Tertian Fever; yet becauſe
we are ignorant of the Nature of the
Blood, which is this Seat of the Di-
ſeaſe, its Hiſtory does not help us to
any Indication, which if anſwered
will

will work a Cure, but we are obliged to the ignorant Indians for our knowledge in curing this Difeafe. And here again to fhew the Neceffity of the Knowledge of the Animal Oeconomy, and how vain a thing Empiricifm is, tho' a more noble Specifick than the Bark was never known, yet we are frequently forc'd, when Intermitting Fevers are complicated to call in to our Affiftance the Knowledge of the Animal Oeconomy, and by Vomiting, Purging and other proper means, to render that Specifick ufeful which before was of no effect.

If the Animal Oeconomy were perfectly underftood, and the Hiftories of Difeafes exactly known, the right Method of curing each Difeafe might be evidently and certainly deduced; and therefore when the Hiftory of a Difeafe is exactly known, if the right Method of curing it cannot be deduced, it muft be becaufe the Animal

Oeconomy is not understood; and from hence it follows that our Skill in curing of Diseases whose Histories are exactly known, (abstracting what we are obliged to Empiricks for) is always proportional to our Knowledge of the Animal Oeconomy.

The Animal Oeconomy is its self a considerable Part of natural Philosophy, and our Bodies are strongly influenced by Variety of Diets, and so many things from without, that indeed the whole study of Nature seems to be useful to him that would understand it. And every discovery in things that affect us, seems to be an Improvement of Physick. Some of the Ancients have indeed left us very judicious and accurate Histories of Diseases, but since the discovery of the Circulation of the Blood, and the late Improvement of natural Philosophy, our Reasonings upon these Histories, in order to find out the Seat and Nature

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of the Diftemper and from them to deduce a right Method of curing, and the whole Practice of Phyfick by the Invention of many ufeful Remedies, is fo much refined, that who ever fhould affirm the contrary, would feem to me neither to have read the Ancients nor to be acquainted with the Practice of the Moderns.

But notwithftanding the great Advantages Phyfick has received from natural Philofophy, it muft be owned, that it has likewife received a very great detriment from the too common Method of philofophizing; that is by laying down of Principles not drawn from the Phœnomena of Nature, but uncertain Fictions of the Brain; fuch as are the firft and fecond Elements of the Cartefians, which are purely Chymerical, and have no Foundation in Nature; and yet their whole natural Philofophy depends upon them: Tho' their reafoning upon fuch fictitious

a 2 *tious*

tious *Principles* were *juſt*, yet *no Phœnomenon of Nature demonſtrating their Exiſtence, the beſt that con'd be ſaid of their Philoſophy is, that for ought we know, it is meerly poſſible*; *but that Nature does actually work this way, can never be ſhown, till the truth of their Principles can be demonſtrated. Moſt Theories of Diſeaſes are built upon ſuch Principles, and therefore we never can have any Certainty, or indeed ſo much as a Degree of Probability, that the Indications drawn from them are right, or ſuch as if anſwered, would cure the Diſeaſe. If a Man may ſuppoſe any Principles which are not evidently falſe, he may at the too common looſe way of reaſoning, give a thouſand Solutions of the Nature of every Diſtemper, all equally true, and all indicating different Methods of curing. Tho' ſuch a Knowledge may ſatisfie the* Curioſity

Curiosity of a Philosopher, yet it can be no sufficient ground for establishing the Practice of Physick eupon. For a Man to hazard his Lif (and he ought to be more cautious of another's) upon the truth of an Hypothesis which is barely possible, is to run a greater Risque than he does, who ventures his Estate in a Lottery, where it is only possible, but not at all probable that he should be a Saver.

But this sort of Phylosophy is not only useless, but it is also prejudicial to Physick; for Men being generally fond of the Productions of their own Brains have studied these more than they have done the Operations of Nature in the several periods of Diseases, and have not stuck to mould and frame Diseases to answer their Hypotheses; so that most of the late Histories of Diseases, are only Philosophical Romances, and contain no-

thing of that diligent Obſervation of Nature which gained Hippocrates immortal Honour, and without which it is impoſſible that ever the Art of Phyſick ſhould be improved.

But ſuch is the Narrowneſs of the Humane Intellect, that few Men are fitted for various Studies, or even for the ſeveral Parts of the ſame Science. Many have been very nice and exact in making Aſtronomical Obſervations, that have had but a very moderate Skill in Geometry, and ſuch as have excelled in this have been deficient in that. And Men either from a want of Integrity and a Senſe of that Truth and Juſtice that is due to Mankind, or from a natural Fondneſs of their own Qualifications, and an Unwillingneſs to think any thing of which they are ignorant, neceſſary to the Science they profeſs, have generally recommended and extolled thoſe Parts which they beſt

beſt underſtood themſelves, but ban-
tered and decryed thoſe they were
leſs skilled in, tho' not leſs neceſſa-
ry and uſeful. Natural Phyloſophy
and the Hiſtories of Diſeaſes muſt
go hand in hand in the improving
the Art of curing; it is not poſſible
to make any uſe of the laſt without
the Knowledge of the firſt. And
I may venture to ſay, that there is no
Man that practiſes, but who does it
upon ſome Knowledge of the Animal
Oeconomy, or ſome notions of his own
which are more or leſs clear accord-
ing to his Skill in natural Philoſo-
phy. And for the Truth of this,
I appeal to Dr. Sydenham's *own*
Writings, who by his philoſophyzing
has evidently ſhewn us the Neceſſity of
that Science, he ſo much decryed, and ſo
little underſtood. He was undoubted-
ly a great Man, and the World will
always be obliged to him for his ac-
curate Hiſtories of Diſeaſes, but

there is no Man without Errors, and where one of his deserved Character falls into a Mistake, it does a great deal more hurt, than if hundreds of others of lesser Note had been guilty of the same.

The following Treatises contain a few Thoughts about some of the principal Parts of the Animal Oeconomy; It was the Consideration of the Use of the Vena Porta which gave me the first hint to think that the several Humours of the Body were formed by the Attraction of the Particles of the Blood; which when I had communicated to my Brother, he was pleased to see his Theorems of Attraction illustrated by so eminent an Instance, and sent me the Demonstration of the third Proposition.

The first that I know of who, to explain Secretion, thought it necessary to consider the state of the Blood at different distances from the Heart, was the

the ingenious Dr. Cockburn; and 'tho he was not then aware of this Principle of Attraction; yet he wisely foresaw that different Velocities of the Blood were requisite for secerning of different Fluids.

As the Learned Dr. Gregory *has, shewn us, in the Preface to his Astronomy; that the Gravitation of the Heavenly Bodies towards one another was known to the Ancient Philosophers; so this Power by which the small Particles of Matter attract one another was the Doctrine of* Hippocrates, *(a) whose whole Philosophy is built upon a certain* Propension *which some things have to one another, whereby they* attract, *retain and alter one another.* Galen *(b) does assert this Attraction to be*

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(a) Vide Mr. *Le Clerc's* Hiſtoire de la Medicine.
(b) Præterea conſpirabile & confluxile totum corpus eſſe, Naturamcue omnia juſte & artificioſe peragere, facultatibus ſcilicet præditam, quibus ſingulæ particulæ convenientem ſibi ſuccum
ad

*be an universal Power in Matter and
(c)compares it to the Power by which
a Loadstone draws Iron.* (d) Hippocrates *explains the manner that purgative Medicines operate just as we
have done.* And Galen *in his Treatise* de Purgantium Medicamentorum Facultate, *does bitterly inveigh
against all those who in opposition to
Hippocrates did assert that all purges,
purged all Humours indifferently ;
and concludes that every purgative
Medicine draws to its self its proper*

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ad se trahunt, attractum vero coalescere, accrescereque omnibus suis partibus faciant. *cap.* 12.
lib. 1. de Natural. Facultat. Ostensum est a nobis in Commentariis de Potentiis Naturalibus,
Naturam uniuscujusque particulæ, quatuor uti
potentiis, attractiva proprii alimenti, & ejusdem
retentiva. *Comment.* 1. *Aphor.* 22.

(c) Ergo ad quem modum trahatur in commune investigemus ; quo porro alio, quam sicut a magnete lapide ferrum, qui scilicet talis
qualitatis trahendæ vim habet. *Lib.* 2 *Cap.* 7. de
Natural. Facultat.

(d) Τὸ γδ φάρμακον ὀκόταν ἐςϡβῆ ἐς τὸ σῶμα, πρῶτον μὴ ἄγει, ὃ ἂν αὐτέῳ χΤ φύσιν μάλιςα ἦ τ ἐν τῷ σώμαϊι ἐνεόνϊων. ἔπειϊ ϡ ϗ ταλλ᾽ ά ἕλκῃ τε ϗ καθαίρῃ.

Humour

Humour. And he strenuously main-
tains a Vis Attractrix *in Nature a-*
gainst Epicurus, Asclepiades, Erasi-
stratus, *and others in his Book* De
Naturalibus Falcultatibus. *All which*
does sufficiently show that this Attra-
ction of the small Particles of Matter
is no Innovation in Philosophy.

   The maner by which I do sup-
pose the Glands do seperate the seve-
ral Humours from the Blood, is much
the same with that of Dr. Morland's
published in the Philosophical Transa-
ctions. What I have said concerning
the Quantity of Blood is sufficient to
show how little reason common Opini-
ons are sometimes grounded upon. And
the Difficulty of the Subject, and the
new Method of handling it, will I
hope procure this short Essay a fa-
vourable Reception. The Theory of
Muscular Motion does follow so natu-
rally and easily from the Principle
of Attraction, that one would be al-
most

most tempted to believe it the genuine Method of Nature. The Determination of the Vis Elaſtica *was the Thought of the Learned* John Bernouli; *but this way of demonſtrating it was communicated to me by my Brother: I am too ſenſible of my own Inabilities to perſue thoſe Thoughts which I have only ſtarted, and I ſhould be pleaſed if they were of any uſe to Men better qualified to make Diſcoveries in Nature.*

Tho' any one with a moderate Skill in the Mathematicks may underſtand theſe Diſcourſes, yet without that no one can judge of their Truth, and Uſefulneſs *in explaining the Animal Oeconomy.*

ERRATA.

PAge 10. line 20. read *diſtance.* p. 14. l. 11. r. *deſcribe the Hyperbola b s a.* p. 17. l. 2 for or r. *for* : l. 11 dele *is attracted.* p. 26. l. 20. and 21. r. $p : x :: t^2 : T^2 + o^2 : O^2$, that is $p : x :: t^2 + o^2 : T^2 + O^2$ and therefore $= \dfrac{p + T^2 + O^2}{2 + o^2}$ p. 40. l. 2. r. *Branches.* p. 65. l. 18. r. *Sudorificks.* p. 145. l. 9. for *a hundred* r. *a thouſand.* p. 176. l. 8. for *Secretion* r. *Section.*

O F

Animal Secretion.

IN explaining the manner, how the several Fluids of the Animal Body are separated from the Blood, I shall shew,

First, *How they are formed in the Blood, before they come to the place appointed for Secretion.* And,

Secondly, *I shall demonstrate in what manner they are separated from the Blood by the Glands.*

The Blood of all Animals, when drawn out of the Body, does naturally, and of itself, divide into two different parts: Of which the Red does in a little time coagulate, but

The Blood consists of attracting Particles.

B   the

the Serum remains fluid.   If we view a drop of Blood with a Microfcope, we difcern a number of Red Globules fwimming in a limpid Fluid ; and perceive how the Globules, attracting one another, unite like Spheres of Quickfilver, which, as they touch, run into one another : And confequently the Blood divides into two parts.

The Serum confifts of attracting Particles.   After the Coagulation of the Red Globules of the Blood, if we examine the Serum with a Microfcope, we find in it likewife a great number of Corpufcles of various Figures and Magnitudes, fwimming in a limpid Fluid.   Thefe do not attract and unite with one another as the former did, till fome part of the Fluid, in which they fwim, has been evaporated by Heat; and then they likewife attract one another, and form a Coagulum, as the Globules did.   This

This therefore is matter of fact, that the Blood confifts of a fimple and limpid Fluid, in which fwim Corpufcles of various Figures and Magnitudes, and endued with different Degrees of an attractive force. Now of fuch Particles, as the Blood confifts of, muft the Fluids be compofed, which are drawn from it; and as in the Blood the Particles attract one another, and cohere together, fo likewife may the Particles of the Fluids, which are feparated from it.

Moft of the Liquors we know are form'd by the Cohefion of particles of different Figures, Magnitudes, Gravities, and attractive Powers, fwimming in an aqueous Fluid, which feems to be the common Bafis of all. Why are there fo many forts of Water, differing from one another in Properties? Is it not, becaufe of the Corpufcles of Salts and Minerals

Moft Fluids confift of attracting Particles.

with

with which the Element is impregnated? What elfe is Wine, but Water impregnated with the Particles of the Grape, and Ale with Particles of Barley? Are not all Spirits the fame Fluid faturated with faline or fulphureous Particles? And all Liquors are more or lefs fluid, according to the greater or fmaller Cohefion of the Particles, which fwim in this Aqueous Fluid; and there is hardly any Fluid without this cohefion of Particles, as is apparent by the Bubbles which ftand upon the Surface of Water, Wine, and even of fome Spirits.

The Secretions confift of attracting Particles.

But that fome of the Fluids, which are fecerned by the Glands from the Blood, are actually compofed by the Cohefion of feveral forts of Particles, is very evident. We know that in Milk there are three or four feveral forts of Subftances, and yet

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when it is examined by the Microscope it appears, like Blood, to consist of very small Globules, swimming in a limpid Fluid. Urine has the same Appearance, and contains perhaps more Principles: And there is no doubt but that Tears, Spittle, and Sweat are all compounded Liquors. If some of the Fluids which are secreted by the Glands are not easily resolved into their compounding Parts, we can no more conclude from thence, that they are not compounded, than we can that the Blood is not, because it does not separate into about thirty different Fluids of which it is composed, and which are constantly extracted from it by the Glands.

If the Particles, which attract one another, are still more powerfully attracted by the Particles of the Fluid in which they swim, than by *The Reason why it is not evident in all.*

one

B 3

one another, they can never of themfelves feparate from the Fluid; and this is the cafe of all Salts dif-folv'd in a large quantity of Water and of Urine, when it neither breaks nor fettles. But if the Par-ticles, which fwim in the Fluid, are more ftrongly attracted by one ano-ther, than they are by the Fluid in which they fwim, then this Fluid muft neceffarily go into parts; and the Corpufcles uniting, will either fink, fwim, or afcend in the Fluid, according to their fpecifick Gravi-ties, unlefs there fhould be fo many interftices within the coagulated Mafs, as will receive the greateft part of the Fluid. From hence it is plain that the red part of the Blood confifts of Particles which attract one another, more than they do the watry Fluid, in which they fwim; and that the other Par-ticles

ticles, which are in the watry Fluid
of the Serum, are more attracted by
it than by one another. But if
part of this watry Fluid be eva-
porated, by this means, the Par-
ticles attracting approaching nearer,
the Force of their Attraction is in-
creafed, and then they unite; and
confequently this force muft be much
ftronger in Particles that are very
nigh one another, than when they
are at a diftance.

This Power, by which the Parti- *This At-*
cles of the Blood attract one ano- *traction is*
ther, is the fame with that which is *an univer-*
the Caufe of the Cohefion of the *fal Power*
Parts of Matter: And was firft com- *in Matter.*
municated to me by my Brother at
Oxford, above feven Years ago; who
had no fooner difcovered it, but
he deduced from it the Cohefion
of the parts of Matter, the Caufe
of the Elafticity of Bodies, of Fer-
menta-

mentations, Diffolutions, Coagula-
tions, and many other of the Ope-
rations in Chymiftry. And fince it
will appear, that the whole Animal
Oeconomy does likewife depend
upon this attractive Power; it feems
to be the only Principle, from which
there can be a fatisfactory Solution
given of the *Phænomena*, produc'd
by the *Minima Naturæ*; as that other
attractive Principle, which is of a
different kind from this, and was
firft difcovered by the incompara-
ble Sir *Ifaac Newton*, demonftrative-
ly explains the Motions of the great
Bodies of the Univerfe: Which is
not in the leaft difturb'd by the attra-
cting Power we now fpeak of, which
only exerts its felf in Particles that
are at a fmall diftance from one
another. Now, that there is fuch
an attractive Power in Nature as
this we have mentioned, I think,

can

can be denied by none, that duly confider the Experiments and Reafons given for it, by Sir *Ifaac Newton*, in the Queftions annexed to the Latin Edition of his Opticks.

From this Principle that the Blood confifts of Corpufcles of various Figures and Magnitudes, and endued with various Degrees of an attractive Power, and that of fuch Particles the Fluids fecerned by the Glands are compofed; I fay, from this Principle (for which we have ocular Demonftration) I fhall endeavour to fhew how the Corpufcles that compofe the Secretions are formed in the Blood, before they arrive at their fecerning Glands: having firft laid down the following Propofitions, being only fo many of the Laws of Attraction as at prefent we have occafion for, the reft
being

being contained in my Brother's Theorems, publifhed in the *Philofophical Tranfactions.*

Prop. I. *There is a Power in Nature by which each Particle of Matter attracts every other Particle, with a Force that increafeth in a greater Proportion than that, by which the* **Squares** *of the diftance decreafe,* viz. *in a reciprocal triplicate, or quadruplicate Proportion to the diftances.*

For were the Particles, that compofe the attracting Body, endued with a Power that attracted only with a Force reciprocal to the Squares of the Diftances, the Attraction would not be much ftronger at the Contact, than at fome determined Diftances from it: As is evident in the Cafe of Gravity, which arifes from a Power of attracting reciprocally as the Squares of the Diftan-

ces;

ces; Bodies being of the fame Weight, when they touch the Earth, as they are at an hundred Feet diftance. But by all Experiments, this Power is much greater at the Contact, or Extremely near it, than at any determined diftance. The Particles of Salt diffolved in a large quantity of Water, do not fenfibly attract one another, till part of the Water has been evaporated; by which means approaching each other, their attractive Force increafes, they run to one another, and uniting form Cryftalls, whofe Parts have a ftrong Cohefion. And therefore the Force, by which each Particle attracts every other Particle, muft encreafe in a much greater Proportion, than that by which the Squares of the diftances decreafe.

Prop.

Prop. II. *The attractive Force is* cæteris paribus *proportional to the Solidity of the Particles.*

The attractive force of a Particle is compofed of the Sum of all the Attractions of the Parts of that Particle: Now thefe Parts are moft numerous in the moft folid Particles, and therefore *cæteris paribus*, their attractive Force is ftrongeft.

Schol. This Propofition is to be underftood of the fmalleft Particles of Matter, and not of the Corpufcles made up of thofe Particles. For Corpufcles may be fo compounded, that the moft folid and compact Particles may make up the lighteft Corpufcle, if the Interftices between the Particles be large, fo that few of them may be diffufed thro' a great Space: Such a Corpufcle, tho' it confifts of Particles that are endued with a ftrong attractive

Power,

Power, may yet be fpecifically ligh-
ther than another, which confifts of
Particles not fo folid, but clofer to-
gether. And fuch fort of Corpufcles
I conceive all Salts to be, whofe
Particles of the laft Compofition are
very folid, but that there are great
Interftices between thofe Particles,
into which the Water rufhing with
a force, being ftrongly attracted,
diffolves the Texture of the Cor-
pufcles.

Prop. III. *If Particles of Matter
attract each other with a Force, that
is in a reciprocal triplicate, or a
greater Proportion of their diftances,
the Force by which a Corpufcle is
drawn to a Body, made up of fuch
attractive Particles, is infinitely grea-
ter at the Contact, or Extremely near
it, than at any determined diftance
from it.*

Suppofe

Suppofe the Sphere A H B com-
pofed of Particles, that attract a
Corpufcle P with a Force recipro-
cally proportional to the Cubes of
their Diftances. Draw the Tangent
P H, and from H let fall the per-
pendicular H I, bifect P I in L,
and raife the Perpendiculars L l,
A a, *Ss*, B b, and make S s = to S I :
with the Afymptots L B, L l thro'
s, defcribe the Hyperbola b B a,
and the Area a A B b — the rect-
angle

angle 2 A S x S I will reprefent the Attraction of the Corpufcle P by the 81 Prop. of Sir *Ifaac Newton's* Principles.

But when the Corpufcle P comes to the Sphere, and touches in A, then the Points P, L, A, I, and H, coincide, and A a becomes the Afymptot of the Hyperbola, and the Area a A B b a becomes infinite, and the rectangle 2 A S x S I being finite, the Area a A B b a — 2 A S x S I will be infinite; and confequently the Force, by which the Corpufcle P is attracted by the Sphere, will be likewife Infinite.

If the Sphere confifts of Particles that attract in a reciprocal quadruplicate Proportion of their diftances, the Force, by which a Corpufcle will be drawn to the Sphere, will be as $\frac{1}{PS^3 \times PI}$. Now when the Corpufcle comes to touch the Sphere, P I becomes $= 0$, and confequently whatever is divided by it, becomes infinite, and therefore the attractive Force of the Sphere at the Contact, being proportional to $\frac{1}{PS^2 \times PI}$, will be infinite.

Prop. IV. *If a Body confifts of Particles attracting with a Force that is in a reciprocal Proportion to the Cubes of the diftances, or in a greater; and if this Force is not infinitely greater than the Force of Gravity at the Point of Contact, or extremely near it, at any determined diftance from the Point of Contact, it muft be infinitely lefs than the Force of Gravity.* This

This is clear by the laſt Propoſition: Or in that Caſe, the Force of Attraction in a Corpuſcle removed from the Contact is infinitely leſs than at the Contact, or extremely near it; but at the Contact it is not infinitely greater than the force of Gravity by Suppoſition: therefore the Force, by which a Particle removed at a determined diſtance from the attracting Body is attracted, is infinitely leſs than the Force of Gravity.

Prop. V. *The force, by which the Particles of Matter attract each other, when extremely near the Contact, is not infinitely greater than the force of Gravity.*

This is evident: becauſe in the ſtrongeſt Coheſion of Particles touching one another, we find that the Weight of ſome Bodies will pull the Particles aſunder, tho' that Body may be prodigiouſly greater and

C   heavier

heavier than the Particles united. Sir *Isaac Newton* calculates from the Inflection of the Rays of Light, that this force near the Contact is 10000 0000 0000 0000 greater than the Force of Gravity.

Corol. Particles removed at a determined distance from the Body attracting, are not acted upon by it; because this Force must then vanish, or, which is the same thing, be infinitely less than the Force of Gravity.

Prop. VI. *A large Particle attracts not more strongly than a small one of the same Solidity, but a Diversity of Figures causes different Degrees of Attraction in Particles, that are otherwise the same.*

This attractive Power acts only on such Particles as are extremely near; and therefore of a large Particle, the remotest parts conduce nothing

nothing to Attraction : and for the same Reason the attractive Force varies, according as the Particles are Cones, Cylinders, Cubes, or Spheres, and *cæteris paribus* a Spherical Particle, has the strongest attractive Power

Prop. VII. *If Particles swimming in a Fluid, attract one another more strongly, than they do the Particles of the Fluid, the Force, by which they come to each other, will be that by which their attractive Force exceeds the attracting Force of the Fluid.*

For the Particles of the Fluid, that lie directly between the attracting Particles, being more pressed than the other ambient Particles ; they will from the Nature of Fluidity, with that excess of Pressure, drive the other Particles out of their places, and make way for the attracting Particles to come together.

Prop. VIII. *If Particles fwim-ming in a Fluid, are more attracted by the Fluid, than by one another, they will recede from one another, with a Force that will be equal to the difference of their mutual Attra-ction, and the Attraction of the Fluid.*

For the ambient Particles of the Fluid attracting more ftrongly, will with their excefs of Force draw the other Particles to themfelves, and make them to recede from one another.

Prop. IX. *The Force, by which Particles attracting one another cohere, is greater* cæteris paribus, *where the Contact is greater.*

For the parts that are farther re-mov'd from the Contact, conduce nothing to the Force of the Cohe-fion ; and a greater Power muft be requifite to feparate two Particles, which

which cohere in two points, than two Particles which cohere only in one point, if the Degree of Cohesion be equal in each point. Thus two polished Marble-stones (suppose a Foot square) adhere more strongly than any other two Bodies of a Foot square, which are not so solid, but have more Pores and Interstices between their parts, and which will not receive so good a polish, by which the parts come to a close contact with one another.

Prop. X. *If the attracting Corpuscles are elastick, they must necessarily produce an intestine Motion, greater or lesser, according to the Degrees of their Elasticity and attractive Forces.*

For after meeting they will fly from one another with the same Degree of Velocity (abating the resistance of the Medium) that they met

C 3 together

together with; but when they approach other Particles in their Refilition, their Velocity muſt increaſe, becauſe they are afreſh attracted, and therefore meeting a ſecond time, they will recede with a greater Velocity than they did at their firſt Concurſion: and ſo their Velocities will be increas'd by every Concurſion and Refilition, which muſt neceſſarily produce a ſenſible inteſtine Motion; and the ſtronger their attractive Force, and the greater their Elaſticity, their Concurſions and Refilitions will be the more ſenſible.

Prop. XI. *Particles attracting one another in a Fluid, moving either with a ſwift or ſlow progreſſive Motion, attract one another juſt the ſame, as if the Fluid was at reſt, if all the Particles move equally; but an unequal Velocity of the Particles does mightily diſturb their Attractions.*

The

The Particles do all by Hypothe-fis move equally, and confequently the progreflive Motion of the Fluid does not alter their diftances, that is to fay, it does not repel them from one another; and confequently they muft attract one a-nother with the fame Facility, as if the Fluid was at reft. But if fome Particles move fafter than others, fome muft change their Po-fition in refpect to each other, and thofe parts, which by the force of Attraction would have come toge-ther, will by this unequal Motion be carried from one another. Thus Salts do not cryftallize, nor the terreftrial Particles of Urine attract one another, and unite, till the Water, in which they are diffolved, is almoft cold; and the inteftine Motion of its Particles, caufed by heat, is quieted.

Thefe

These are the Laws, by which Secretions are firſt formed in the Blood, before they are ſeparated by the Glands. The Particles of the Blood returning by the Veins mutually attract one another, and cohering form Globules too big for any Secretion; and therefore there was an abſolute neceſſity, that they ſhould be broken and divided in the Lungs by the force of Reſpiration: which becauſe it is commonly thought to be inconſiderable, by reaſon we are not ſenſible of it, I ſhall therefore here make an Eſtimate of it.

The Force of the Air upon the Blood in breathing determined

It is demonſtrated by the Writers of Hydroſtaticks, that Weights, which force out of the ſame Tube equal Quantities of the ſame Fluid, are to one another as the Squares of the times the Fluid is forced out in. But if the times are equal in which

the

the fame Quantity of the Fluid is
forced out thro' unequal Tubes,
then the Powers are reciprocally as
the Orifices of the Tubes; and
therefore Powers which thruſt out
the fame Quantity of a Fluid thro'
unequal Tubes, are to one another
in a reciprocal Proportion, com-
pounded of the Squares of the Times
and Orifices of the Tubes.

Now that I might know by what
force the Air is thruſt out of the
Lungs in Expiration, I took a thin
Hogs-bladder, which I could eaſily
blow up with the Breath of one
Expiration; and having moiſtened
it, that it might neither reſiſt the
Air in blowing up, nor the Weights
which were laid upon it, I fix'd a
ſmall Tube, whoſe Diameter was
$\frac{1}{10}$ part of an Inch, to the Neck of
the Bladder; then filling the Blad-
der with Air, I put a Weight of

<div align="right">2 *lib*</div>

2 *lib* 4 Ounces on the top of it:
And having repeated the Experiment several times, I found that
this Weight squeez'd all the Air
out of the Bladder thro' the small
Tube in the space of 25 Vibrations
of a Pendulum, which vibrated Seconds of a Minute.

Let P stand for 2 *lib* 4 Ounces,
or 36 Ounces, O for the Diameter
of the Tube, T for the time of 25
Seconds, and suppose ɔc to be the
Power, by which the Air is thrust
out of the Lungs in Expiration,
o the Diameter of the Aperture of
the *Larynx* (which I shall suppose
to be $\frac{3}{10}$ parts of an Inch) let t be
the Time spent in an ordinary Expiration, which is commonly $1''\frac{1}{4}$ or
$1''25$. then $P : ɔc : T^2 : t^2 : T^2 + o^2 : O^2$, that is $P : ɔc : t^2 \times o^2 : T^2 \times O^2$, and therefore $ɔc = \frac{P \times T^2 \times O^2}{t^2 \times O^2}$
$= \frac{36 \times 625 \times .01}{1.5625 \times .09} = \frac{225}{0.140625} = 1600$
Ounces

Ounces, equal to 100 *lib*: which is the force by which the Air is thruſt out of the Lungs every Expiration. But being Action and Reaction are equal, the Preſſure of the Air upon the Lungs every Expiration is equal to the Preſſure of an 100 *lib* Weight. If the Gravity of the Air was always the ſame, and if the Diameter of the Trachea Arteria, and the time of every Expiration were equal in all, this Weight upon the Lungs would be always the ſame. But ſince we find by the Barometer, that there is 3 Inches difference between the greateſt and the leaſt Gravity of the Air, which is a $\frac{1}{10}$ part of its greateſt Gravity; there muſt be likewiſe the difference of ten *lib* Weight in its Preſſure upon the Lungs at one time and another: for the Momenta of all Bodies, moved with

with the fame Velocity, are as their Gravities. This is a difference, which fuch as are Afthmatick muft be very fenfible of, efpecially if we confider that they likewife breath thicker, that is, every Expiration is performed in lefs time; if in half the time, and the fame Quantity of Air drawn in, then the Weight of the Air upon the Lungs muft be 400 *lib*, of which ÷ part is 40 *lib*, and confequently Afthmatick People upon the Rife or Fall of the Barometer, feel a difference of the Air almoft equal to half its Preffure in ordinary breathing. Again, if the *Trachea Arteria* is fmall, and its Aperture narrow, the preffure of the Air increafes in the fame Proportion, as if the times of Expiration were fhorter: and therefore a fhrill Voice is always reckoned amongft the prognoftick Signs

of

of a Confumption, becaufe that proceeds from the narrownefs of the *Larynx*, or *Trachea Arteria*; and confequently encreafes the Preffure of the Air upon the Lungs, which upon every Epiration beats the Veffels fo thin, that at laft they break, and a Spitting of Blood brings on a Confumption apace.

I fuppofe, no body doubts whether this Preffure of the Air upon the Lungs in breathing be fufficient to break the Globules of the Blood, and to diffolve all the Cohefions they might contract in their Circulation thro' the Arteries and Veins. And when the Blood is thus diffolved and thrown out by the Heart into the *Aorta*; it is evident that the reunion of the Particles requires more or lefs time, according to their feveral attractive Powers, even tho' they all moved with the

By this Preffure of the Air, the Cohefions of the Globules of the Blood are diffolved.

s   fame

same Velocity, and in the same Direction.

How the Union of the Parti-cles is hin-dered near the Heart. But neither doth this happen, for a Fluid moves thro' a Cylindri-cal or Conical Veſſel (ſuch as the Arteries are) with a greater Velo-city at the *Axis* than at the Sides. And again, the Blood is thruſt in-to the *Aorta* by the whole Force of the Heart, and Fluids when they are preſſed preſs *undequaque*, by which means the Arteries are dila-ted, and the Blood moves not only forwards, but likewiſe preſſes per-pendicularly on the Sides of the Arte-ries; and as the Sides of the Arte-ries (being Elaſtick) return, they preſs the Blood from them every way, which muſt produce an in-teſtine Motion, and by the 11th Propoſition hinder the Attraction of the Particles, and by this frequent and ſtrong Colliſion of the Particles

of

of the Blood againſt the Sides of the great Arteries, the Coheſions of the Particles, if any of them happen to unite, will be immediately diſſolved. Again, this inteſtine Motion muſt greatly increaſe upon the account that many of the Particles of the Blood are elaſtick: for by this Reſiſtance of the Sides of the Veſſels, they muſt neceſſarily hit one againſt another, and being elaſtick, reflect from one another, and ſo increaſe the inteſtine Motion of the Blood by the 10th Propoſition. Upon this inteſtine Motion of the Blood depends its Heat, which therefore is every where proportional to the *impetus* of the Particles againſt the Sides of the Veſſels, ſuppoſing the Elaſticity of the Particles every where the ſame. Now the *Impetus* of the Particles againſt the Sides of the Veſſels decreaſes, as

the

the Sum of the Cavities of the Veſſels increaſes: and conſequently where the Sum of the Cavities of the Veſſels is greateſt, there the inteſtine Motion of the Blood is leaſt, and the attractive Power of the Particles *cæ= teris paribus* is greateſt.

The Effects of Steel. By the by, we may obſerve how that Steel, being an elaſtick Body, heats the Blood more than any other Mineral; and how by its Elaſticity, the Force of its own Particles in removing Obſtructions, as well as thoſe of the Blood, increaſe, and therefore it is a better Deobſtruent, than ſome other Minerals, which have a greater Gravity.

What Particles unite first. The Particles, which unite firſt after the Blood is thrown out of the Heart into the great Artery, muſt be ſuch as have the ſtrongeſt attractive Force; and ſuch as have the leaſt, unite laſt: and all the intermediate

termediate ones according to their feveral Natures. The Particles endued with the ftrongeft attractive Powers, are by the 2d and 6th Propofition, the moft folid fpherical Corpufcles, and the Quantity of their Contact being the leaft by the 9th Propofition, the Secretion, which they compofe, muft be the moft fluid, and fuch is the Liquor in the *Pericardium.*

The Salts are Corpufcles that are ftrongly attracted, and have a moft clofe Union with the Fluid of Water; for tho' the Lungs may divide the Particles of Salt from one another, yet ftill they firmly adhere to the aqueous Humour in which they fwim, and therefore they may likewife at firft be drawn off: upon which account the Kidneys have their Situation fo near to the Heart. And indeed, they could not have

The Reafon of the Situation of the Kidneys.

D   been

been placed at a greater distance, and have separated such a Quantity of Urine as they now do, not only upon the account of the great Quantities of Blood they receive where they are; but likewise, because if they had a more distant Station, other Particles must have united with the Salts and aqueous Particles (as in their present Station some terrestrial Particles do) and consequently the Urine could not have been distilled such as it is now, or at least but in a small quantity.

What Particles are longest in uniting.

The Corpuscles, which are the slowest in uniting, must be such as have the weakest attractive Force, which by the 2d and 6th Proposition, are such as have the least Solidity, and such as have their Surfaces the most extended; and therefore Corpuscles, which have plain Surfaces, are longer in uniting than

than ſpherical Corpuſcles, but when
united, they cohere more ſtrongly
by 9th Propoſition, and compoſe
the moſt viſcid Fluids: and there-
fore the moſt viſcid Secretions, ſuch
as the Mucilage of the Joints, are
ſeparated at the greateſt diſtance
from the Heart, where the Sum of
the Cavities of the Arteries is great-
eſt, the *Impetus* of the Blood a-
gainſt the Sides of the Veſſels (which
is always proportional to the Velo-
city of the Blood) ſmalleſt, and
conſequently where the Particles
move almoſt with an equal Veloci-
ty, and therefore the Attractions of
the weakeſt are not diſturbed by
the 11th Propoſition.

The Gall which is ſecerned by the
Liver, and the Seed by the Teſticles,
do ſeem to be two conſiderable Obje-
ctions againſt what has been ſaid.
But I will make it appear that they

D 2   are

are so far from proving any thing against this Doctrine of Secretions, that they are the greatest Arguments that could possibly be urged for the truth of it. Nothing does more evidently demonstrate the Intentions of Nature in her Operations, than the various Methods she is sometimes forced to take to bring the same thing about.

This Doctrine illustrated by the Separation of the Gall in the Liver.

This is most eminently remarkable in the Secretion of the Gall: which, being to be mixed with the Chyle as it comes out of the Stomach into the *Duodenum*, could no where be so conveniently secerned from the Blood, as where the Liver is placed. Now had all the Branches of the Celiack Artery carried all the Blood to the Liver, from which the Gall was to be separated, it is evident, considering the nearness of the Liver to the Heart, and the intestine Motion of the

the Blood, that so viscid a Secretion, as the Gall is, could never have been formed in the Blood, and consequently, could never have been secreted by any Gland in that place. In this case Nature is forced to alter her constant Method of sending the Blood to all the parts of the Body by the Arteries. Here she forms a Vein (which is no Branch of the *Vena Cava*, as all the others are) and by it she sends the Blood from the Branches of the Mesenterick and Celiack Arterick (after it has passed thro' all the Intestines, Stomach, Spleen, Caul, and Pancreas) to the Liver. By this extraordinary Contrivance the Blood is brought a great way about, before it arrives at the Liver; and its Celerity is extremely diminished, that all the Corpuscles, which are to form the Gall may have sufficient time to attract

D 3　　　one

one another, and unite before they come to their fecerning Veffel. And thus we have found out the ufe of the *Porta*, which, notwithftanding it makes fo confiderable a Figure in the animal Body, yet perhaps no part was ever lefs minded, or had its ufe lefs underftood by the Writers upon the animal Oeconomy.

But that this is moft certainly the ufe of the *Porta* will more evidently appear, if we confider what Nature ftill does farther in profecution of the fame Defign.

The Cavities of all the Arteries increafe as they divide. The Sum of the Branches, which rife immediately from the *Aorta*, is to the *Aorta* as 102740 is to 100000: but as if this Proportion was too little to effect the defign of Nature, before the Blood arrives at the Liver, the Branches, which imme-
diately

diately fpring from the Trunk of the Mefenterick Artery, increafe in a much greater Propotion. The Figure of this Artery, as it lies in the middle of the Mefentery, is after this manner.

And in that Body, from which I took the following Proportions, I found 21 Branches to fpring immediately from its Trunk. In fuch parts of which the Trunk of the Mefenterick Artery is 15129

The 1ft Branch is	2136
2	1936
3	2136
4	2104
5	4489
6	1936

7	2601
8	3136
9	1681
10	3025
11	625
12	1369
13	1024
14	1849
15	1936
16	529
17	729
18	1156
19	1024
20	1156
21	841

The Sum of all $\overline{37418}$

By these Proportions it appears, that the Sum of the first Branch is much more than double to the Trunk of the Mesenterick Artery; and therefore the Velocity of the Blood in them is much less, than

4   half

half what it is in the Trunk. But
becaufe the other Branches do not
exceed one another fo much, I fhall
therefore fuppofe that the Branches
are only double to their refpective
Trunks, and that there are only
fix Series of Divifions between the
Trunk, and the evanefcent Artery:
whereas moft of the Branches have
fo many Series, whilft they run up-
on the Mefentery, and many more
upon the Inteftines, fo that what
we may have exceeded in reckon-
ing the Branches double to their
Trunks, is more than made amends
for in fuppofing fo few Divifions.
Now from this eafie Suppofition,
the Velocity of the Blood in the fe-
veral Series will decreafe in the
fame Proportion as thefe Numbers
increafe 2, 4, 8, 16, 32, 64. And
therefore the Velocity of the Blood
in the evanefcent Artery will be

64

64 times lefs than it is in the Trunk of the Mefenterick.

As the Trunk of the Mefenterick Artery bears a leffer Proportion to its Branches, than the *Aorta* does to its Branches; fo the Branches of the Mefenterick Artery are likewife lefs in Proportion to their conjugate Veins, than the *Aorta* is to the *Vena Cava.* The defcending Trunk of the *Aorta* below the Emulgents is to the *Vena Cava* at the fame place, as 324 is to 441. But a branch of the Mefenterick Artery is to its correfponding Branch of the *Porta*, as 9 to 25: and therefore the Blood in the Branches of the *Porta* moves above 177 times flower than it does in the Trunk of the Mefenterick Artery, and that only upon the account of the encreafe of the Diameters of the Veffels. So neceffary was it to abate

the

the rapid inteſtine Motion of the Blood, which might hinder the co-aleſcence of the Particles for the Formation of the Bile. The Blood is indeed no where without an in-teſtine Motion; but where the Sum of the Cavities of the Blood Veſſels is greateſt, there the inte-ſtine Motion being moſt languid, the Particles which hit againſt one another, do not refile, but unite together; and a very languid inte-ſtine Motion, by bringing Particles nearer to one another, which other-ways would not have come toge-ther, conduces to encreaſe the Com-bination of Particles.

We have now ſeen how Na-ture has provided for the Forma-tion of the Bile in the Blood, which paſſes thro' the Meſente-rick Artery. We ſhall next con-ſider what Care is taken of that

which

which is conveighed by the Celiack
Artery to the Liver: For it feems
it was neceffary to fend a larger
quantity of Blood to the Liver, than
could be difpofed off thro' the In-
teftines. Part of the Blood of the
Celiack Artery is fpread upon the
Stomach and Caul, and its Veloci-
ty diminifhed, as we have feen in the
Inteftines; but ftill all the Blood,
which thefe parts could receive,
was not fufficient for the Liver, and
there was no more room for the
divifion and expatiating of the Vef-
fels thro' fuch a large Space as the
Mefentery, and a long Tract of Guts.
How therefore muft the Velocity
of the reft of the Blood (to which
the Inteftine Motion is always pro-
portional) be abated? Nature has
here another extraordinary Contri-
vance, fhe empties the Blood entire-
ly out of the Veffels into a large
fpongy

fpongy Bowel, or rather Ciftern provided for that intent and purpofe. I know not the Dimenfions of the Splenick Artery, but the Circumference of the Celiack being $\frac{1}{2}$ an Inch, or ,5, its Square is ,25; and therefore the Square of the Splenick, which is a Branch of it, cannot be above ,18. Now the Dimenfions of the Spleen are 6 Inches in length, 3 or 4 in breadth, and 2 in thicknefs. I fhall therefore make this eafy Suppofition for the more ready Calculation, that it is a Cylinder of 2 Inches Diameter, and therefore the Square of its Circumference being 36, the Blood muft move 200 times flower in the Spleen, than in the beginning of the Splenick Artery: and is longer before it gets to the Liver, than that which paffes thro' all the Inteftines. Is not this the long fought

for

for ufe of the Spleen? So produ-
ctive is one fimple Truth of many
others.

From all this Art and Contrivance
it is evident Demonftration, that
the Intent of Nature was to dimi-
nifh the Velocity of the Blood, and
that fuch a flow Motion was ab-
folutely neceffary for the fecerning
of the Bile in the Liver. If the
Humours which are feparated by
the Glands are at all times and
places the fame in the Blood, and
not formed after the manner de-
monftrated, what need was there
for diminifhing fo confiderably the
Velocity of the Blood? let the
Blood move faft or flow, they would
be always the fame, and always in
an equal aptitude to be fecerned.

The Pro-   The Particles, which compofe
portion of
the Bile to the Bile, bear a very fmall Propor-
the reſt of tion to the reft of the Blood, as is
the Blood.
                                            evident

evident from the great quantity of Blood that is carried to the Liver, and the small quantity of Bile that is separated by it. In a large Dog, whose *Ductus Cholidochus* was near as big as a Man's, I could never gather above two Drachms in an Hour. Now there is throwm into the *Aorta* every Hour about 4000 Ounces of Blood: and it appears by the Proportions of the Arteries, that the Mesenterick and Celiack are to the rest, as 1 to 8; and therefore 500 Ounces of Blood: are carried every Hour to the Liver. And since only two Drachms of Bile are separated from it, the Bile must be to the Blood, at least, as one is to two thousand. It is by reason of this small Proportion of the Bile to the Blood, that it was so necessary to allow so much time for the Attraction of the Particles which

form

the Bile. From this Contrivance
of the *Porta*, the Bile receives ano-
ther Advantage, not lefs confide-
rable than the Diminution of the
Velocity of the Blood: and that is
the Blood paffing thro' fo many
different parts before it comes to
the Liver, parts with the greateft
part of its *Lympha*, by which means
the Particles, that compofe the Bile,
approaching nearer to one another,
are by their mutual Attraction fooner
united. And the confideration of
thefe two Contrivances does high-
ly confirm the truth of this Theory
of Secretion: For the Diminution
of the Velocity of the Blood, and
the Subtraction of the *Lympha* can
agree in no other end, than the u-
niting of the Particles of the Bile.

What has been faid concerning
the Bile, does fo evidently prove
this Doctrine of Secretions, that
                                    there

there feems to be no room to doubt
of it, even tho' we could not clear
the like Difficulty, as to the Forma-
tion of the Seed. Yet here again,
we meet with another Manifeftation
of the truth of it, and we find Na-
ture purfuing the fame Intentions,
tho' in a different manner, the
Structure of the parts not allow-
ing either of the former Contri-
vances.

The Blood is carried to the Te-
fticles by the Spermatick Arteries;
which, contrary to the conftant Me-
thod of Nature in framing the other
Arteries, are fmalleft, where they
fpring from the Trunk of the great
Artery, and immediately dilate to
a confiderable bignefs: which evi-
dently fhews, that there could be
no other defign in it, but to retard
the Velocity of the Blood. We
cannot fuppofe that the only Inten-

Of the Se-
cretion of
the Seed.

E   tion

tion was, that a fmall quantity of Blood might go to the Tefticles: becaufe then there had been no occafion for giving the Artery a different Figure from all others; that narrow Orifice would have been fufficient of its felf for that purpofe, which the widenefs of the Artery immediately afterwards does neither hinder nor further. The Orifices of the Spermatick Arteries were fo fmall, that I could not meafure them, when I took the Dimenfions of the other Arteries; and yet they are hardly gone from the *Aorta* before they dilate as big, if not bigger than one of the Lumbals, which is 434, 2: Now if we fuppofe their Orifices to be each 17, 3, then the Blood will move 25 times flower, where the Artery dilates, than it does at its Orifice. Again, we conftantly find that all the parts of

the

the Body are supplied with Blood
by small Arteries from the nearest
Trunks. If this Method had been
observ'd in sending the Blood to
the Testicles, they had received
their Arteries from the Iliacks; and
they had ran but a little way, before
they had come to the end of their
Journey. But instead of this, two
small Arteries are made to arise from
the *Aorta*, a little below the Emul-
gents, and to march above a Foot
before they come to the Testicles.
Now if we consider that the Velo-
city of the Blood in the Sperma-
tick Artery, is 25 times slower than
it is at its Orifice, that is, in the
Aorta; and that the Velocity of the
Blood in the Iliacks, can be but a
very little less than it is in the *Aorta*,
where the Spermaticks arise; the
Blood must move 25 times slower
to the Testicles, than if it had gone

E 2 after

the ordinary manner from the Ili-
acks: and becaufe the Space it runs
thus flowly, is at leaft fix times longer
than if it had gone from the Iliacks;
therefore it muft be 150 times
longer in going to the Tefticles,
than if it had gone according to
the common Courfe of Nature.
So that the inteftine Motion of the
Blood is not only allayed, but fuf-
ficient time is afterwards allowed
the Particles, which are to compofe
the Seed, to attract and coalefce
before they arrive at the Tefticles.

Some Ob-
jections
anfwered.   Perhaps it may be faid, that the
Mucus of the Nofe, and the Wax
of the Ear are feparated, where
the Blood is not fo languid as their
Vifcidity feems to require: But I
anfwer, that they are Fluids which
fall into open Paffages, where the
Air having free Admiffion, carries
off part of their aqueous Fluid; and
the

the Remainder becomes thick, as the *Serum* of the Blood does, when heated. Befides, we muſt remember, that tho' the Coheſion of the Particles depends upon their Figures, yet the Force by which they attract one another, is likewiſe in Proportion to their Solidities. So that Particles of equal Magnitudes, and ſimilar Figures may cohere equally ſtrongly, yet the moſt ſolid will ſooneſt unite. Hence it is, that of two Fluids equally viſcid, the heavieſt may be ſeparated in Glands nearer to the Heart than the other; and that two Fluids of different viſcidities may be ſeparated at the ſame vicinity to the Heart, if the quantity of the Contacts of the Particles be ſuch, as will make amends for their want of Solidity.

Moſt, if not all the Secretions contain a greater or leſſer Proportion

of

of the aqueous Fluid, which makes them more or lefs vifcid; yet that which contains the greateft quantity, may confift of Particles endued with a very fmall and flow attractive Force: and confequently fuch a Fluid cannot be feparated by any Gland fo near the Heart, as that which has a lefs Proportion of the aqueous Fluid, and which confifts of Particles endued with a ftronger attractive Force; and this laft Fluid may be much more vifcid than the other, whofe Particles are more diluted by the watry Fluid. Now how it comes to pafs that a greater or leffer Proportion of the aqueous Fluid is feparated in any Gland, I fhall fhew in the fecond part of this Difcourfe.

But that the different Vifcidities of the Secretions do not depend only on the greater or leffer Proportion

tion of the aqueous Fluid, is evident from the foregoing Propofitions; unlefs any one can fuppofe that the Blood confifts only of one fort of Particles : which Suppofition, befides that it contradicts matter of Fact, can never account for the Secretion of fo many different Fluids. And that the Diverfity of the Attractions in the Particles is the Reafon, why various Velocities of the Blood, and diftances from the Heart, are required for fecerning of different Liquors, is moft evident from what has been faid concerning the Bile, and the Seed. If only a greater or leffer Proportion of the aqueous Fluid had been requifite for feparating of different Sorts of Fluids, that might have been done any where, as fhall be fhewn afterwards; and Nature had not been put to

E 4 fo

fo many Shifts and Contrivances, as we have already feen.

Some Fluids may be fecerned any where. As fome Fluids are only to be feparated in certain Velocities of the Blood, and at certain diftances from the Heart; fo there may be others that may be feparated any where, and in any Velocity of the Blood. Thefe are fuch as confift of Particles always in an equal Aptitude to be fecerned, and tho' fome of them may contain feveral forts of Particles, yet the Nature of thefe Fluids does not depend upon the Attraction and Cohefion of their Particles. Such a fort of Secretion is the *Lympha*, which is a watry Fluid fecerned in all parts of the Body, for making the Chyle more liquid. If it be faid, that fince the *Lympha* might have been feparated any where, and that it ferves only to dilute the Chyle, that there ought

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to

to have been a particular Gland
some where for it in the *Abdomen*,
as being the more proper place:
I answer, that a large quantity of *Lympha* was necessary for diluting
the Chyle, as appears by the nume-
rous *Lympheducts*, which discharge
themselves into the *Receptaculum
Chyli*, *Ductus Thoracicus*, and Sub-
clavian Veins.   And if such a quan-
tity had been separated by a Gland
or Glands in the *Abdomen*, appro-
priated to that use, they must have
had very large and considerable Ar-
teries.   The Liver has $\frac{1}{7}$th part,
and the Kidneys near $\frac{1}{7}$th more of
the whole Blood, which passes thro'
the *Aorta*; and if the Lymphatick
Glands had had $\frac{1}{7}$th part more
(which is the least they could have
had) these three parts would have
had near one half of the Blood,
and the other half must have served
all

Why the Lympha is secerned in several places.

all the reſt of the Body : which would have been a very unequal Diſtribution of the Blood. Beſides, Nature is always very ſimple and frugal in her Operations; ſhe never is at any unneceſſary trouble: and I will ſhew in the ſecond part of this Treatiſe how the *Lympha* may be drawn off, by Glands appointed to ſeparate other Fluids; ſo that for this Operation ſhe makes no Part, is at no expence of Blood: but ſhe muſt have been at a very great one, if ſo much *Lympha* had been drawn off by appropriated Glands.

Of the Secretion of Animal Spirits. I take the animal Spirits to be another Fluid of this kind. They, undoubtedly, conſiſt of by far the ſmalleſt Particles in the Blood, as appears by the minuteneſs of their ſecerning Glands ; and therefore they not being formed by the Co-
heſion

hesion of other Particles, might have been separated any where. Yet the Animal Oeconomy receives a great Advantage by the distant Station of the Brain from the Heart; for if it had been placed nearer, and received the Blood, still divided into its smallest Particles, by the force of the Air in the Lungs; such Particles might have entred the Glands, as, afterwards cohering to one another, might have obstructed such extremely narrow Channels. Now the Brain being placed at such a distance, the Particles, that by their attractive Power form Corpuscles, will have sufficient time to coalesce, and their Magnitude will hinder their entring into the Glands. For if it should happen, that these Particles should enter the Glands, and there unite together, they would then obstruct the Passage

fage to the Nerves, and produce Apoplexies, Palfies, Coma's, &c.

The Particles, of which the animal Spirits confift, being of fuch extreme Finenefs, their quantity can bear but a fmall Proportion to the other Fluids in the Blood; and confequently there was a necefity of a prodigious Number of Glands to feparate them from the Blood; and this is the Reafon of the great Bulk of the Brain.

Of the Number of different forts of Particles in the Blood.

The Operations of Nature are always the moft eafie and fimple. Now how much more eafie is it to have the feveral Secretions formed after the manner which has been demonftrated, than to fuppofe as many different forts of Particles in the Blood, as there are Fluids feparated from it? It is not eafie to determine, how many different forts of Particles are in the Blood. Indeed,

deed, Phyfick feems in nothing fo defective, as in the Knowledge of the Nature of the Blood. But if the fame Pains had been beftowed upon it in a Mechanical Way, that have been, in vain, fpent in fearch of its Principles by Chymifts; we had long e'er now had a more perfect Knowledge of its Nature, than ever we can have by Chymiftry: which can only fhew how, by Art, its parts may be altered, not what parts it contains.

A few different forts of Particles varioufly combined, will produce great Variety of Fluids, fome may have only one fort, fome two, fome three, or more; and perhaps the aqueous Fluid is the common Bafis of all the Secretions. If we fuppofe only five different forts of Particles in the Blood, and call them a, b, c, d, e, their feveral Combinations,

nations, without varying the Proportions, in which they are mixt will be thefe following.

$$ab : ac : ad : ae :$$
$$bc : bd : be : cd :$$
$$ce : de : abc : adc :$$
$$bdc : bde : bec : dec :$$
$$abcd : abce : acde : abde :$$
$$bcde : abcde.$$

But whether there are more or fewer in the Blood, I fhall not determine.

Of the Operation of Medicines, which alter the quantity of the Secretions. The manner that Medicines operate, which encreafe or diminifh the quantity of any Secretion, is both eafie and obvious from what has been faid. There is no need of giving Medicines Commiffions for fearching and opening the Sluces of particular Glands; nor have they a general Power to attenuate

and

and diffolve all the Cohefions of
the Blood, for then we might ftill
ask why their Operations appear
only on one fort of Glands? Why
does Jallap carry the diffolved Hu-
mours thro' the Glands of the In-
teftines, rather than any other?
Why does Mercury falivate, or Ni-
tre force Urine? All Theories of
Secretions have laboured at this
point, which naturally difclofes its
felf in this.

The feveral Humours being for-
med by the different Cohefions of
the Particles of the Blood, the quan-
tity of Humour fecerned by any
Gland, muft be in a Proportion
compounded of the Proportion, that
the Number of the Particles, co-
hering in fuch a manner, as is pro-
per to conftitute the Humour which
paffes thro' the Gland, bears to the
Mafs of Blood, and of the Propor-
tion

tion of the quantity of Blood that
arrives at the Gland. And hence
it follows, that where there is a
determined quantity of a certain
Humour to be feparated, the num-
ber of the Particles that are proper
to compofe the fecerned Liquor,
muft be reciprocally proportional
to the quantity of Blood that ar-
riveth at the Gland: and therefore
if the quantity of the Secretion is
to be increafed, the Number of the
Particles is to be increafed; if the
Secretion is to be leffened, the
Number of the Particles, that are
proper for fuch a Secretion, is to
be leffened in the fame Proportion.
Medicines therefore which can alter
the Cohefions and Combinations of
the Particles, can either increafe or
diminifh the quantity of any Secre-
tion. Thus for example, fuppofe
the Humour, which paffeth thro'
the

the Glands of the Inteſtines to be compoſed of three or four ſeveral ſorts of Particles, that Medicine which will eaſily cohere to theſe Particles, and cohering increaſe their mutual Attractions, ſo as they unite in greater Numbers at, or before they arrive at the Inteſtines, than they would have done if the Medicine had not been given, muſt neceſſarily increaſe the quantity of Humour, which paſſeth thro' the Glands of the Inteſtines, if the quantity of Blood which arrives at the Glands is not diminiſhed in the ſame Proportion, as the Number of the Particles is increaſed. After the ſame manner do Diureticks, Sudorifick, and Medicines, which promote all other Secretions, operate.

If Medicines, which encreaſe the *Specifick Purges.* quantity of any Secretion, operate by uniting to, and augmenting the

F   attractive

attractive Force of the Particles, which compose the Humours to be secerned: may not the Particles of some Humours, sooner, more easily, and strongly unite to the Particles of some sort of Medicines, than to another sort? And consequently, may not different Humours require different purgative Medicines to carry them off thro' the Glands of the Intestines? And does not this reestablish the Doctrine of Specifick Purges, confirmed to the Ancients by Experience and Observation, but rejected by the Moderns thro' a false Philosophy?

The Knowledge of Secretion necessary for the understanding the Nature of Diseases The Animal Body is nothing but a Machine, whose Actions and Motions are all performed by Fluids, secerned from the Blood, and Secretion is the Spring of all the animal Functions. By its means the Heart beats, the Blood circulates, the

the Limbs are moved, and the Aliments concocted and digested, and in a word, the whole Animal Oeconomy, and Life depend upon it; the Blood its self seeming to have little other use, besides the recruiting and renewing the secerned Liquors. I say therefore, since Life and Health depend upon the Secretions; so likewise must all Diseases, which are said to be universally in the Blood, and many of those which affect particular parts. If the quantity and quality of all the Secretions are such as are proper and useful for the several Purposes, for which by Nature they are intended, how is it possible but that the whole Animal Oeconomy must be in right Order, and that Body in a good State of Health? Unless we can suppose an Error in the first Contrivance of the Body; a Suppositi-

F 2 on

on no Man in his Senſes can make.
But if the quantity of any Secreti-
on exceeds its due Bounds, what
Diſorders it makes is evident from
a Diarrhæa, Diabetes, Epiphora,
Sweatings, &c. If the quantity of
any Secretion falls ſhort of what it
ought to be, the Effects are of no
leſs pernicious Conſequence, as ap-
pears from a Suppreſſion of Urine
in the Kidney, from the Jaundice
and a Stoppage of Perſpiration.
And that the quality of the Secre-
tions altered do likewiſe create
great Diſorders, is obvious from
the Pains of the Colick, of a Di-
arrhæa, and Dyſentery, from the
Sharpneſs of Urine, which ſome-
times produces Ulcers in the Blad-
der and Kidneys; and even the
Spittle is known to corrode the
Mouth. I have choſen to give moſt
Inſtances of ſuch Secretions, as are
pro-

properly Evacuations, becaufe their
Effects are apparent to every body,
and cannot poffibly be faid to be
only a Notion.   But if the Altera-
tion of thofe is of fuch ill Confe-
quences, what Effects muft an un-
due quantity, or the vitiated Qua-
lity of thefe, which are retained in
the Body, and employed about the
neceffary Functions of Life, produce?
The Diforders they create, are not
fo evidently the Effects of their ill
State, tho' by a juft reafoning, we
may fometimes deduce them; and
therefore a right Notion of Secre-
tion muft be of the greateft ufe and
Importance, for the underftanding
of moft Difeafes.

I fhall only inftance in a Diabetes, *Of a Dia-*
and from this Doctrine of Secretion *betes.*
explain the Nature of that Difeafe
hitherto unknown.   The Symp-
toms, which precede a Diabetes,
F 3   are

are little wandring Pains, and fre-
quent Twitchings of the Tendons.
These are followed by a profuse
Evacuation of a clammy, sweetish
Urine, as if Honey were dissolved
in it; which is constantly attended
with a Thirst, quick Pulse, Faint-
ness, and loss of Strength: all which
depend upon the Flux of Urine,
and increase and diminish in the
same Proportion with it. The e-
vident Cause of this Distemper is
an habitual drinking of strong Li-
quors, and the more spirituous they
are, the sooner and more violently
they bring it. But a Diabetes is
not always caused by an habitual
drinking of strong Liquors, for
sometimes it proceeds from some
internal and latent Cause. How-
ever, the Nature of the Disease is
always best known, by considering
what

what effects the evident Caufes of it produce in the Body.

By an habitual drinking of ftrong Liquours, it comes to pafs in pro-cefs of time, that the *Serum*, or thin part of the Blood, contains a large Proportion of a fpirituous Flu-id; or that part of the Serum, which fhould be Water, is for the great-eft part Spirit. Now the Salts of the Urine or Blood, will not dif-folve in vinous Spirit, that is, the Particles, of which the Salts confift, are more ftrongly attracted by one another, than they are by fuch a Fluid, as by Experiments it appears. And therefore the Quantity of Salts in the Blood, will be daily increa-fed, and circulating thro' the Ca-pillary Veffels, muft irritate the fine Fibres, and caufe little Pains and Twitchings all over the Body. But when the Serum is full of thefe

F 4 Salts,

Salts, the distance between them and the Globules of the Blood will be less; and consequently they will attract the Globules of the Blood, more strongly than the Globules attract one another; and the Globules, or red Part of the Blood, will be dissolved and diffused thro' the Serum of the Blood. And this again is confirmed by Experiments; for nothing does render the red part of the Blood so Fluid, and keep it more from coagulating, when drawn in a Cup, than Urinous Salts and Spirits. When the Red part of the Blood is thus dissolved and united to its Serum, it will with the Serum be carried off thro' the Glands of the Kidneys, and being united to the Salts, will alter their Figures and Properties, as Litharge and Corall do the Salts of Vinegar, giving them a sweet Taste.

All

All quick Evacuations of the Veffels muft diminifh the quantity of Fluid, feparated in the Glands, as will be feen in the following Treatife about the Quantity of Blood ; and therefore the greater quantity of Urine is voided in a fmall time, the lefs *Saliva* and animal Spirits will be fecerned by their refpective Glands : and confequently Thirft, Faintnefs, and lofs of Strength will increafe, as the quantity of Urine excreted increafeth.

This being the State of the Blood, it is evident that the Indications of Cure, are to diffolve the Cohefions of the Salts with the Blood, and to carry them off by Urine. Thefe can be anfwered by nothing fooner or better than Waters, which are therefore to be drunk in large quantities. And of all Waters, thofe which have a Tincture of

Lime

Lime are beſt, becauſe Lime does
ſtrongly attract Urinous Salts.

I could ſhew the uſefulneſs of
this Doctrine, in explaining ſome
Symptoms of Feavers, Rheumatiſms,
Small-Pox, and ſome other Diſea-
ſes, which are not thought to de-
pend upon Secretion; and from
thence deduce what things are hurt-
ful, and what uſeful in the ſeveral
Methods of curing them: but that
would carry me beyond my preſent
Deſign, and perhaps may more ful-
ly be illuſtrated ſome time hereaf-
Of Rheu- ter. I will only take notice, that
matiſms. from this Theory, we have a plain
and eaſie Account of the Thickneſs
of the Blood in Rheumatiſms; for
it is known, that this Diſeaſe ari-
ſing generally from a Cold, the O-
rifices of all the cuticular Glands
are extremely contracted, ſo that
ſcarce any Fluid, but the aqueous
can

can paſs them: and therefore the
other Particles, by the Diminution
of the aqueous Fluid being brought
nearer to one another, will attract
and cohere more ſtrongly. And
this Coheſion will be greateſt in the
Extremities, where the Motion of
all the Particles is near equal by the
11th Propoſition. And does not *Of the*
this evince the Neceſſity of diluting *Gout.*
the Blood in the Cure of Rheu-
matiſms? This equal Celerity of
the Particles of the Blood in the
Extremities, is likewiſe the Rea-
ſon why the Concretions of the
Gout are formed there; unleſs by
frequent Debauches, or a decay of
Nature, the Motion of the Blood
becomes ſo languid, that theſe Par-
ticles eaſily attract one another in
the Blood Veſſels of the Bowels,
where I have ſhewn that the Moti-
on of the Blood is alſo very ſlow:

4   and

and then such Remedies as warm and increase the intestine Motion of the Blood, and thereby disturb the Attraction of the gouty Particles, relieve the Bowels, and send the peccant matter to the Extremities again. To this Attraction of the Particles in the Urine, is owing the Formation of Gravel and Stone in the Kidneys and Bladder, and the Nucleus of the Stone in the Bladder, being almost equally surrounded every where with the Fluid of Urine, its Attractions are almost every where equal; and therefore the Stone is made up of so many parallel Shells or Laminæ. Now from this it demonstratively follows, that copious and liberal drinking must necessarily prevent the growth of both: For by that the attractive Particles are removed at a distance too great to attract

Of the Stone.

attract one another. Provided always that the Drink be such, as is not highly saturated with Particles, which easily and stronly attract one another; what these Drinks are, they, who know the Nature of the Liquors which are commonly drunk, will easily understand.

As this Principle of Attraction *The Ope-* will account for most Diseases; so *rations of* I doubt not, but that by it likewise *Medicines* the Operations of all sorts of Medi- *by Attra-* cines may be explained. For ex- *ction.* ample, Medicines which thicken the Blood, are such as consist of very small Particles, and endowed with a strong attractive Force, by which easily cohering to the Globules of the Blood, they increase their Attraction to one another, and so produce a Coagulation, or at least a thickening of the Blood. On the contrary, if a Medicine consists of

<div align="right">such</div>

such Corpufcles, as will eafily unite
with the aqueous Particles, and in-
creafe their Attraction; fo that they
attract the Globules of the Blood
with a greater Force, than thefe
Globules attract one another, then
will the Globules recede from one
another, be diffufed thro' the Se-
rum, and the Coagulum be diffolv-
ed. A Gonorrhea is undoubtedly

The Ope-
ration of
Mercury.

produced by a very active Salt,
which being ftrongly attracted by
the Humour in the Glands, and
uniting to it, like the Acids of Salt
and Vitriol to Mercury in the Pre-
paration of Sublimate, forms a ve-
ry *virulent pus*, which corrodes
the Veffels, and produces Ulcers.
And as Sublimate lofes its corro-
five Faculty, by the Addition of
more Mercury, which ftrongly at-
tracts its acid Salts; fo Mercury
mixt with the Blood, attracts the

acid

acid Salts of the Pox, and uniting
to them, carrys them off, either
bp Stool, Spittle, or otherwife.
This Power, by which Mercury at-
tracts acid and fharp Salts, is the
Reafon why Cinnabar is fo good a
Medicine in fixt and vagrant Pains,
as in a Rheumatifm: for the Urine
of Rheumatick Perfons is found up-
on Examination, not to contain its
due quantity of Salts, which there-
fore being retained in the Blood
turn acid, and produce Pains.

Now, who can doubt of the
Truth of a Principle fo fimple, and
yet which like a Mafter-key opens
Works of very different Contri-
vances, and difclofes an Uniformi-
ty in all the Operations of Nature;
fo that every one may fee and read
the fame Thought and Hand in the
Contrivance, and framing of every
part of the Univerfe. By it we fee
the

the Reason why the Branches of all
the Arteries in the Body, have the
Sum of all their transverse Sections
greater than the transverse Section
of the *Aorta*; for if it had been
otherwise, there could have been no
Mucilage separated for the easy
Motion of the Joints, without such
a Structure as the Spleen at every
Joint, where this Mucilage was ne-
cessary. By it the Reason not on-
ly of the general Structure of the
Vessels is demonstrated, but like-
wise the Necessity of the Frame and
Situation of the particular parts, as
of the Lungs, Spleen, *Porta*, and
of all the Glands. By it the Na-
ture of the Blood and all the Secre-
tions may be explained. By it
the whole animal Oeconomy, and
all its Disorders, the several Di-
seases incident to the Body, the
Nature of their Remedies, and the
ways

ways of their Operations may be accounted for. This is that grand Principle, by which all the Particles of matter in this Planet are actuated. By which, but with a different force, all the Planets are carried round the Sun; and as the projectile Velocity of the Planets, adjusted to the Sun's Attraction, causes them to move in their several Orbits; so the Velocity of the Blood, adapted to the Attraction of its Particles, causes the several Humors to be secerned at certain distances from the Heart by their respective Glands.

I shall now proceed to the second thing I proposed to shew; which is, *The manner whereby the several Fluids, after they are formed in the Blood, are separated from it by the Glands.*

G   This

This does depend intirely upon the Figure and Structure of the Glands; which muſt be therefore firſt determined. As Truth when plain and evident does of itſelf diſpel all falſe Opinions, ſo the true Structure of the Glands being once demonſtrated; there will be no Occaſion to refute the Doctrine of Ferments; nor the Hypotheſis of Tubes differing as to the Figures of their Orifices, both which have been ſeveral times demonſtrated to be falſe.

That the Glands are nothing but Convolutions of ſmall Arteries, the greateſt and moſt accurat Anatomiſts of this Age, *Malpighius*, *Bellini*, and *Nuck* have diſcovered. And indeed that all the Veſſels of the Body, in which the Liquors are continually moving, can have no

no other than a cylindrical or Conical Form, is demonstrable from the Nature of Fluids, whose Pressure is always perpendicular to the Sides of the containing Vessel, and equal at equal Heights of the Fluid: If therefore the sides of the Vessels are soft, and equally yeilding every where (such as are all the Tubes in the Body of a *Fœtus*) they must by the Pressure of their contained Fluid, be equally every where distended; and consequently the Section of such a Vessel perpendicular to its Axis must be a Circle, and therefore the Vessel must be either a concave Cone or Cylinder, or at least such a Figure whose transverse Section is a Circle.

The Circular Orifices therefore of the Glands can only differ in Magnitude, and all sorts of Parti-

cles

cles of a lesser Diameter than that
of the Orifice of the Gland may
enter it; so that without some far-
ther Contrivance, that Fluid which
contains the biggest Particles, must
likewise consist of all the Particles
of all the other Secretions; neither
could any Fluid thicker than the
Blood be separated from it, be-
cause of the great Proportion of
the aqueous Fluid, whose Particles
being vastly smaller than any other;
and invisible to the best Micro-
scopes, must enter all the Glands,
and be mixt with the secerned Fluid.

How this inconveniency may be
prevented, and how the Particles
of any size may either be separa-
ted by themselves, or with any a-
signed Proportion of the aqueous
Fluid, or of other lesser Particles,
I shall now endeavor to show.

<div align="right">suppose</div>

Suppofe A B to be a fmall evanefcent Artery, and that the Particles of the leaft fize were to be feparated from the reft.
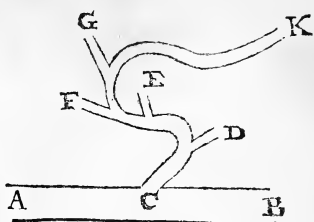
From the fide of the Artery muft arife the Gland or Tube C K, whofe Orifice at C is fuch as is capable of admitting only Particles of the leaft fize, together with the *Aqueous* fluid, thefe therefore will be feparated from all the other Particles of the Blood, and the Tube C K being a Cylinder, they will pafs to its further end K, which is fuppofed to be the Excretory Duct of the Gland.

If the Quantity of the *Aqueous* fluid, feparated with the leaft Particles muft be diminifhed, that fuch a fluid as is requifite, may pafs thro' the Excretory Duct K, from

G 3   the

the Tube C K, you muſt imagine
that ſeveral other ſmaller Canals
go out, as at D, E, F, G, whoſe
Orifices are ſo ſmall, that they ad-
mit no other Particles beſides thoſe
of the *Aqueous* fluid to paſs thro'
them ; and therefore as the leaſt
Particles, together with the *Aque-
ous* fluid paſs along the Tube C K,
the *Aqueous* fluid muſt conſtantly
be diminiſhed, the Quantity of the
leaſt Particles ſtill remaining, the
ſame can paſs no where, but thro'
the Excretory Duct K ; and this
Diminution of the *Aqueous* fluid
will be always according to the
Number of the Canals D, E, F, G,
that is in Proportion to the Length
of the Tube C K, and therefore
according as the Gland is longer or
ſhorter, ſo the more or leſs *Aque-
ous* fluid will paſs thro' the Orifice
of the Excretory Duct K, and con-
ſequently

fequently the fecreted Fluid upon this Account be thicker or thinner.

If the Particles of a middle fize, between the biggeft and the leaft, are to be drawn off from the reft of the Blood. Let the Orifice at the Gland C be juft fo big as to admit thefe Particles, and not any of thofe that are bigger : Thefe Particles therefore, together with the *Aqueous* fluid, and all leffer Particles will pafs thro' the Orifice C, but if the Canals D, E, F, G, are big enough to receive all the other Particles, and too narrow to admit the Particles that are to be feparated; it is evident, that thofe Particles muft arrive at the Excretory Duct K, with what Proportion of leffer Particles is required.

Thus we fee how any fort of Particles may be drawn off, either by themfelves, or mixt with any

G 4 others

others in any Proportion, and this is done in the moſt ſimple manner, only by Arteries, for C K is only a ſmaller Artery, ſtraight, ſpiral, or otherwiſe contorted, and D, E, F, G, are again Arteries ſmaller than it, and if any of theſe are ſo ſmall, as to admit only Particles of *Serum*, they conſtitute lymphatick *Veſſels*; from thence it is that we find *Lympheducts* to ariſe in great Numbers from thoſe Glands that ſeparate thick Humours, as from the Teſticles, Liver, *&c.*

Of the *Quantity* of *Blood* in the *Humane Body.*

I Know not upon what grounds *Phyſicians* and *Anatomiſts* have generally determined the Quantity of Blood in the Humane Body, to be

be between fifteen and twenty five pound Weight. All that I can find is the large Quantities of Blood voided by Perfons dying of violent *Hæmorrhagies*; fo that according to their feveral Obfervations, fome have afcribed a greater, and fome a fmaller Quantity of Blood to the Body. Dr. *Moulin* has allotted by much a fmaller Quantity than any, and gives us the Method by which he determin'd it in the *Philofophical Tranfactions*. He fays, That in a Sheep, which alive, weigh'd 118 *lib.* he found by bleeding it to death, that it contain'd $5\frac{1}{4}$ *lib.* of Blood, which is lefs than $\frac{1}{22}$ part of the Weight of the Sheep. That in a Lamb weighing $30\frac{1}{2}$ *lib.* when living, there was but $1\frac{1}{2}$ *lib.* of Blood, which is about $\frac{1}{20}$ part : Now upon the Suppofition, that a Man's Blood bears the fame Pro-

How Dr. Moulin did determine it.

portion

portion to his Weight, as that of
the Lamb's (which is the greateſt)
had to its Weight, it will follow,
that the Quantity of circulating
Blood in a Man, weighing 160 *lib.*
will not exceed 8 *lib.*

Neither of these Ways juſt. Theſe Eſtimations (tho' widely
different from one another) are
both made from the Quantity of
Blood voided at an open *Veſſel,*
and they are both founded upon
this Suppoſition, that almoſt all the
blood in the Body runs out at the
Wound; a Suppoſition I can by no
means allow to be true, and which
I ſhall evidently ſhew to be falſe.
For ſuppoſe the right external *Ili-
ack* Artery cut aſunder, ſo as that
the Blood may freely flow out of
the Wound : How can the Blood
which is in the right Leg below the
Wound, be emptied ? It is cut off
from the reſt of the Blood above,
which

which fhould drive it forwards, and all the Affiftance it can have from collateral *Branches*, which communicate with it can be but very little, becaufe they themfelves can receive but a very fmall quantity of *Blood*, the *Blood* running all to the Wound, where it finds the leaft Refiftance. The Arteries in the *Leg* can beat no longer, becaufe the Pulfe depends upon the Quantity of *Blood* thrown into them every Syftole of the Heart, which in this Cafe is nothing, and thefe being the only regular Caufes of the Motion of the *Blood*, the *Blood* muft ftagnate in the Crural *Veffels*. All that can be faid is, that the great Arteries will once contract, and may perhaps have fome fmall *Vibrations* afterwards, by which they will thruft the *Blood* into the capillary *Veffels*, and their convulfive

five Motions will fqueeze the *Blood*
forwards in the *Veins* ; but when
an Animal once falls into Convul-
fions by bleeding, it can bleed but
little afterwards, the Motion of the
Heart ceafing ; befides we know,
that neither all Animals, nor all
Parts of an Animal are convuls'd
upon bleeding to death : And tho'
the great Arteries may contract, yet
this Contraction muft be very lan-
guid in the fmall Arteries, which
being innumerable, the greateft part
of the *Blood* will be lodg'd in them,
there being nothing to drive it out
of their contorted Channels, but it
muft ftill remain in them, as like-
wife in the Fibres of the Mufcles,
which appear of a red Colour, only
upon the Account of the *Blood* con-
tain'd within them, their Subftance
being naturally White. Again, tho'
the right and left *Iliack* Arteries
do

do in the natural State receive an
equal quantity of *Blood* ; yet when
a Wound is made in the Right,
thro' which the *Blood* has an eafie
Paffage, this muft receive much the
greateft part of the *Blood* which
comes down the *Aorta,* and confe-
quently the Circulation of the *Blood*
muft be very flow in the left *Leg,*
and no more *Blood* can come from
it, than what is thruft out meerly
by the Motion of the *Body,* or
what flows naturally of its felf in
the ftrait and large *Veffels,* as Fluids
will do to come to an *Æquilibrium* ;
for the fame Reafon the afcending
Trunk or *Branches* of the *Aorta* can
receive but a fmall quantity of
Blood, and therefore the Pulfe in
the Arteries of the *Brain* muft be
very languid or none at all, upon
which Account the Motion of the
Spirits muft ceafe, and confequent-
ly

ly that of the Heart. When the
Aorta begins to be empty (which
muft quickly happen when the
Blood runs out at a Wound of a
large Artery) then the *Blood* ha-
ving little or no Refiftance, will
flow eafily into the empty *Veffel*,
and a very fmall Quantity of it
will enter the Orifices of the Co-
ronary Arteries of the Heart, the
Valves covering them, and confe-
quently the Motion of the Heart
muft ceafe for want of *Blood*.

The great-
eft Effufi-
on of Blood
not from
the larg-ft
Veffel.

It is for thefe two laft Reafons,
that the larger the *Veffels* are that
are wounded, the fooner the Animal
dies; and if the *Aorta* it felf was
cut afunder, there would be a
fmaller Effufion of *Blood* from it,
than from a fmaller Artery: For
fince it is the *Blood* in the *Aorta*
that thrufts forward the *Blood* in
the *Veins*, and makes it pafs from
the

the *Vena Cava* into the right Auricle of the Heart; it is plain, that when the *Blood* in the *Aorta* is intercepted, the *Blood* will be no longer driven thro' the *Veins*, but will ſtagnate in them, no more of it coming to the Heart, than what by reaſon of the Fulneſs of the *Veins* flows into it, and conſequently the Heart throwing but a ſmall Quantity of it into the *Aorta*, the Circulation will be quickly ſtopt, both in the Aſcending and Deſcending Trunks, and there will be no greater effuſion of *Blood* than what can be contain'd in the great Artery which holds but little. Whereſoever the Wound is made, ſo long will the Animal live, as the great Artery keeps full, but whenever that begins to empty, the *Blood* in all its Branches muſt ſtop, and conſequently the Animal muſt die.

The

The *Veſſels* of the *Animal Body*
are not meer unactive Tubes, but
as they may be gradually dilated,
ſo they can gradually contract again;
and as they cannot ſuffer any vio-
lent and ſudden Stretching without
breaking, ſo neither can they im-
mediately contract upon any ſudden
Evacuation.   And therefore when
any great *Artery* is wounded, the
Animal dies after a few Pulſations
of the Heart, the great *Artery* be-
ing immediately emptied : But
when a ſmall *Artery* at a great di-
ſtance from the Heart continues
bleeding ſlowly, all the *Veſſels*
throughout the whole *Body* gradu-
ally contract, ſo that after many
Pounds are evacuated, they may be
as full as they were at firſt, and
conſequently the *Animal* not ſo
much as faint, the *Veſſels* in the
Brain being ſtill kept full, and the
                                    Spirits

Spirits driven forwards in the
Nerves; nor can the Animal die till
such time as the *Veffels* contract no
more. It is for this Reason that
we have no Obfervations, which
give account of fuch large effufions
of Blood, at Wounds of the great
Arteries, as we have from the fmall
Veffels of the Nofe, and from the
Hæmorrhoides ; and therefore Do-
ctor *Moulin*'s Determination of the
Quantity of the whole Mafs of
Blood, which is calculated from the
Quantity, voided at the Carotide
and Jugular *Veffels,* is much lefs
than what others from the Obfer-
vation of *Hæmorrhagies* of fmall
Veffels have determin'd it to be.

This Contractive or Elaftick Pow-
er of the *Veffels* is not equal in all
Bodies ; for in fome it is greatly
diminifh'd by the Vifcidity of the
Blood, and the Obftruction in the

*The Rea-
fon of fain-
ting upon
any fud-
den Eva-
cuation.*

H   Fibres

Fibres and Capillary *Veſſels*, and therefore ſome Men may die of a much leſs effuſion of Blood than others, who perhaps may have a leſs Quantity of Blood. It is for the ſame Reaſon that ſome Perſons faint upon opening a *Vein* of the Arm, whilſt others do not. If this Elaſtick Power of the *Veſſels* is ſtrong and great, then as the Blood is let out, the Arteries of the *Pia Mater* contract, and are kept full as well as the Coronary *Veſſels* of the Heart, and conſequently there is neither Blood nor Spirits wanting for performing the Motion of the Heart ; but it happens juſt otherwiſe, where this Elaſtick Tone of the *Veſſels* is wanting, that is, to ſuch as have a ſoft and looſe Fleſh, a lax and cachectick habit of Body ; and therefore when they require bleeding, it is convenient to

ſtop

ſtop the Blood at ſmall intervals, to give the *Veſſels* time to contract, before the full Quantity that is deſign'd be drawn off; and if they are ready to faint, the ſurprizing them, by throwing cold Water in the Face, to cauſe a ſudden Contraction, and the putting of them into an horizontal Poſture, that the *Veſſels* of the Brain may fill, and the Blood from all the depending Parts, have a more eaſie Reflux, does prevent it. It is the want of the ſame Energy of the *Veſſels* that cauſes ſome to faint upon any ſudden Evacuation by Urine, Stool, or any other ways.

That this is the true Reaſon of fainting upon any ſudden or violent Evacuation, and not the drawing off of the Spirits (as is generally ſaid) appears not only from this, that ſuch as faint upon bleeding at the

A Proof of this Reaſon.

H 2   Arm,

Arm, do not faint upon Cupping, tho' the fame, or a greater Quantity of Blood be drawn off this way, but likewife from the fainting of Perfons tapped for an *Afcites*, if it happens, that too great a Quantity of the Waters is drawn off at once. None can fuppofe that the Spirits, which are in the extravafated *Lympha*, have an immediate Influence upon the Nerves and Heart, that their Subtraction fhould prefently drain the Nerves of Spirits, nor can any think, that the Spirits are fo quickly fpent, as immediately to fuffer upon the account of the want of a Supply from an extravafated Fluid: but the Cafe is this; In an *Afcites*, the defcending Trunk of the *Aorta*, and all its Branches being confiderably compreffed, the Blood muft neceffarily dilate the afcending Branches beyond their natural

natural Bignefs ; but, when the Waters are let out to any confiderable Quantity at a time, the Blood has a more free Paffage into the defcending Trunk , the Sum of the Cavities of both Arteries is augmented, and the Quantity of Blood thrown out every Syftole not being greater, the Arteries cannot be fo much dilated, and confequently the Pulfe becomes fmall and weak, and the Spirits therefore are but flowly propelled thro' the Nerves, the Blood flows but in a fmall quantity into the Coronary *Veffels* of the Heart, and confequently a Syncope muft enfue, till the *Veffels* can recover their Tone, and the Blood in all the Arteries comes to an *Æquilibrium*, and therefore it is neceffary to rarifie the Blood, and roufe the languid Motion of the Spirits by a Cordial.

H 3 That

That the Compreſſion of the deſcending Artery muſt throw a greater Quantity into the aſcending Branches is demonſtration, and that this Quantity is conſiderable, and does affect the whole Machine, is evident from the Fluſhing and Head-ach which ſome feel after a plentiful Meal, when the Stomach and Guts being loaded, preſs upon the deſcending Trunk, and contract its Cavity, which are the Cauſes why a greater quantity of *Blood* paſſes into the aſcending Trunks; on the contrary, if the Cavity of the deſcending Trunk ſhould be dilated, there will be a leſs Quantity of *Blood* thrown into the aſcending Trunks, and conſequently the Effects on the Animal *Body* muſt be at leaſt as ſenſible.

This contractive Power of the *Veſſels* ought to be duly conſider'd,

before

before the leaſt Quantity of Blood be drawn in moſt acute, as well as chronick Diſeaſes; for I could eaſily ſhew how it may be loſt to a great Degree, in a few Hours. And in no Caſe whatſoever is the drawing off a large quantity of Blood at a time juſtifiable, ſince it may be done more ſafely, and to as good Purpoſe at ſmall Intervals. It is evident from the Theory of *Secretions*, that both the Quantity and the Quality of the *Secretions* may be altered by *Blood-letting*, and therefore when the *Blood* is upon a Ferment, and generates new Co-heſions, of whoſe Nature we are ignorant, it is a Riſque, which without evident and cogent Rea-ſons, ought not to be run. But to return,

If we give any Credit to the Obſervations of Phyſicians, we muſt

H 4 believe

A greater quantity of Blood proved from the Observations of Physicians. believe the Quantity of *Blood* in the Humane Body to be above 25 pound Weight. (a) *Rulandus* tells us, that he cured one of a bleeding at the Nose, after he had bled in one Day about Ten pound Weight. (b) *Petrus Borellus* observes, that a full bodied Jovial Taylor lost Ten pounds of *Blood* by the *Hæmorrhoides*, and that he cured him with the Syrrup of dried Roses. (c) *Sckenckius* quotes *Montanus* for one that voided Two pounds and more of *Blood*, by the Piles, every Day for forty five Days together, and was afterwards cured. (d) *Bartholin* says, that he saw one vomit sixteen pound of *Blood* without the least ill Consequence. And he takes Notice of

(a) Rulandus Curat. 57. Cent. x.
(b) Cent. iv. Obf. Lviii. (c) Lib. tert. Obf.
clx. (d) Cap. de Corde.

one

one who bled forty eight pound in three Days by the Nofe, from *And. Argolus.* (a) *Sckenckius* has feveral Obfervations of profufe *Hæmorrhagies* of the Nofe. He mentions a Nun of a thin Habit of *Body,* who by bleeding at the Nofe, fpitting of *Blood,* and with Urine, voided eighteen pound of *Blood* ; fhe was cured by one Drachm of *Philonium Perficum. Brafavolus* cured a Lady of a bleeding at the Nofe ; the *Blood* which he weighed, befides what fell upon the Ground, Linen and Cloaths , was eighteen Pound. *Marcellus Donatus* recovered one of a bleeding at the Nofe, who in two Nights and one Day, bled above twenty pound Weight, as he found by weighing it. And at laft he tells us of one

(a) Lib. de capite Obf. cccxxxiii.

who

who in fix Days bled forty pound
at the Nofe.

Now if the Quantity of *Blood* in
the Humane Body was not confi-
derably greater than its common
Eftimate, thefe Perfons could ne-
ver have furviv'd fuch profufe effu-
fions of their *Blood.* All of them
bled more than Dr. *Moulin* reckons
to be in the Body, and many of
them more, and almoft double of
the largeft Quantity which is al-
low'd of by any : So that either we
muft deny thefe Matters of Fact,
or we muft own, that our higheft
Eftimates of the *Blood* fall much
fhort of the true Quantity. With-
out doubt Men differ in the Quan-
tities of their *Blood,* as well as in
the Weight of their Bodies : But
none of thefe above-mention'd are
noted to have been of a full habit
of Body except *Borellus's* Taylor ;
and

and it is particularly said of the Nun in *Sckenckius*, that she was a spare and thin Woman, and that her bleeding could not proceed from a *Plethora*.

Having therefore sufficiently proved, that the quantity of Blood in the Humane Body must be much greater than the common Estimation : I shall in the next Place endeavour to shew how much at least it is.

By Blood I understand not only the Fluid in the Veins and Arteries, but likewise that in the *Lymphe-ducts*, *Nerves*, or any other *Vessel* of the Body, because they are all Parts of the Blood, separated from it by the Force of the Heart, and many of them by the same Force return to it again ; and therefore, when I speak of the quantity of blood in the Body, I would be understood

What is here meant by Blood.

derftood to mean the quantity of circulating Fluids, of what kind foever they be, at other Times I fhall ufe the Word in its common Signification.

The whole Body made of Veſſels and Fluids. I fuppofe the whole Body is nothing but *Tubes* or *Veſſels* full of *Blood* or *Liquors* feparated from it. This is now agreed on by all who underftand the Fabrick of the Body, and is evident from nice Mercurial Injections of the *Veſſels*, and may be plainly feen by *Microſcopes.* *Leeuwenhoeck* fays, That there feemed to be above 10000 Blood-veffels in the fpace of $\frac{1}{7}$ of an Inch fquare. You cannot prick your Finger with the fineft Needle but it wounds a Blood-veffel. The Fibres of the Mufcles (which make by far the greateft part of the Body) are full of Blood, and the Fibres of the
Bones

Bones are not without their Fluid, as I shall shew afterwards.

I therefore consider the *Vessels* full of Fluids, as so many solid *Cylinders*, and the Coats of the *Vessels*, as so many concave *Cylinders* of the same height, whose Proportion to one another may be thus determined. Let *A B G H* represent the circular Section of a Vessel, of which call the Diameter *A B*, *a*, the Diameter *c d* of the Cavity, *a—b*. Circles being to one another as the Squares of their Diameters, the Square of the whole Section is a^2, the Square of the Cavity is $a^2 - 2 a b + b^2$, which being subtracted from the Square of the whole, there remains $2 a b - b^2$ proportional to the annular Space *A B G H c d f E*, and consequently
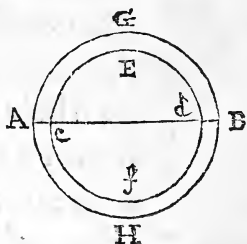
ly

ly in a Body compos'd of such *Vessels* filled with Fluids, the Fluids will be to the Solids, or Coats of the Vessels as $a^2 - 2ab + b^2$ is to $2ab - b^2$.

Several sorts of Vessels.

Now if the whole Body was composed of Veins or Arteries, it were easie to determine the Quantity of Blood in the Animal Body. But we find, that the Coats of the Arteries have a greater Proportion to their Cavities, than the *Veins* have to theirs, and these again have a greater Proportion to their Cavities, than the *Lymphatick Vessels* have to theirs, and there may be one Proportion of the Nerves, another of the Fibres of the Muscles, and another of the Fibres of the Bones, all which ought to be known before the quantity of blood in the animal Body, can be exactly determin'd.

The

The thickneſs of the Coats of the Blood-veſſels may be thus ex-actly found: Slit a piece of a Blood-veſſel, and reduce it to the Form of a *Parallelogram*, then weigh it in Water, and by that means find the Weight of Water equal to it in bulk. This weight reduced to de-cimal Parts of an Inch call, d, and ſuppoſe the length of the *Parallelogram* equal to e, and its breadth $= c$, its thickneſs f. Then $d = e c f$ and conſequently $\frac{d}{ec} = f$ the thickneſs of the Coat of the *Veſſel*.

Thus a piece of the *Aorta* of a Calf I found to be equal to 0.071897 parts of an Inch of Water, its length was 1.1, its breadth 1.28, and therefore its Thickneſs was 0.051. The Diameter of the Cavity of this Artery was 0.407. and conſequently $a^2 - 2 a b + b^2$ equal to 0.165649, and $2 a b - b^2$ equal to 0.093432,

The Proportion of the Blood in the Arteries to the Coats of the Arteries.

0.093432, and therefore if the whole Body was compofed of Arteries or Veffels which had the fame Proportion to their Cavities, as the Arteries have to theirs, the Blood would be to the folid part of the Body, as 1.7 to 1, and a body weighing 160 Pound, would have 100 Pound of blood.

The Proportion of the Blood in the Veins to the Coat of the Veins. After the fame manner I found that the thickneſs of the Coats of the *Vena Cava* of the fame Calf was 0.0097. The Diameter of this *Vein* was 617, its Square is 0.380689, and $2ab - b^2 = 0.02431596$. If therefore the body was compoſed of Veſſels, whoſe Coats had all the fame Proportion to their Cavities, that the Coats of the Veins have to theirs, the Blood would be to the folid part of the body, as 15,6 to 1, and in a body weighing one hundred and fixty Pound, there

there would be above one hundred and fifty Pound of blood.

It is to be obſerv'd, that theſe Proportions of the thickneſs of the Coats of the *Veſſels* to their Cavities were taken when the *Veſſels* were empty, and conſequently when the Coats were thickeſt, and the Diameter leaſt, for all the *Veſſels*, eſpecially the Arteries, ſhrink and contract when they are empty. Let us ſuppoſe the Diameter of the *Cavity* of the Artery which was 0.407, to be increaſed 0.1. the Square of this *Cavity* would be 0.257049, and conſequently the blood would be to the ſolid part of the body, as 2.7 to 1. If the Diameter were increaſed 0.2 the blood would be to the *Veſſels*, as 3.9 to 1. If 0.3, it would be as 5.3 to 1. From theſe Proportions one may judge more exactly to what

How the Bulk of the Blood encreaſes upon a ſmall encreaſe of the Diameter of the Blood-Veſſel.

I De-

Degree the blood is heated or rarified in inflammatory Feavers, by the Largeness of the Pulse : As also how small a Quantity of blood must be thrown out at the Heart every Syftole in languid Feavers when the Pulfe is fmall.

How the Arteries may be dilated in Aneurifms.

It is furprizing to fee how little the encreafe of the Diameter of the Cavity of the Artery diminifhes the thicknefs of its Coats; for if we add to the Square 0.257049, the annular Space which we found to be 0.093432, then 0.350481 is the Square of the Diameter of the whole Artery, that is both of its *Coats* and *Cavity*. The Square Root of this Number is 0.592, from which if we fubtract the Diameter of the *Cavity*, there remains 0.085, the half of which 0.0425 is the thicknefs of the *Coat* of the Artery. Thus I find that the Diameter

meter of the *Aorta* may be encreaſed eight times its firſt bigneſs before its *Coats* become ſo thin as the *Coats* of the *Cava.* This ſhews how prodigiouſly Aneuriſms may dilate the Arteries ; and how, when a large Trunk of an Artery in the Arm, Leg or Thigh is tied, the ſmall Arteries (which all communicate with one another) may dilate to carry on the Circulation of the Blood.

The next ſort of *Veſſels* I come to conſider is the Fibres of the Muſcles, which tho' they may be more bulky, yet they cannot be more numerous than the Arteries; for every Fibre muſt have at leaſt one Artery, and it is probable it has ſeveral. They without doubt have conſiderable *Cavities,* being they ſwell, are blown up, and thereby conſiderably ſhortned when

Of the Quantity of the blood in the Fibre of the Muſcles.

I 2   the

the Mufcles act. And their fides can be but thin, or elfe they could not be diftended by fo fmall a Force. Befides the Blood appears as plainly thro' them as it does thro' an Artery of an equal bignefs, and therefore we cannot judge their fides to be thicker than the Coat of an Artery of an equal bignefs. The Proportion of the thicknefs of their fides to their Cavities is not to be taken after the Manner we have done thofe of the Veins and Arteries, but that we might make fome Eftimate of it, I made the following Experiment.

I took a piece of the Inteftine of a Dog, with part of the Mefentery and *Pancreas Afellii*, and having carefully emptied it of all its Contents, I weighed it exactly with all the Blood in the Veffels, its Weight was one Ounce and a half,

one

one Drachm and eighteen Grains; then I injected warm Water into the Artery, and having sufficiently washed out all the Blood, I blew it up, and hung it up to dry in the Shade; after it had dried about a Week, I weighed it again, and its Weight was two Drachms, two Scruples, and eleven Grains: By which it appears, that it had lost six hundred and thirty seven Grains, and that there remained only one hundred and sixty one Grains. Now this Loss could be only of the Fluids, which being diluted with the warm Water, were the more easily evaporated, and therefore if the Blood in every part of the body bore the same Proportion to the solid Part, that it does to the solid Part of the Intestines, their Proportions would be 3.9 to 1, and a body weighing one hundred and six-

ty

ty Pound would contain one hundred and twenty feven Pound of *Blood*, fo that even the Fibres of the Mufcles are lefs folid than the Arteries. But the Fibres which perform the Periftaltick Motion of the Inteftines, are not fo fpongy as the Fibres of the Mufcles, for we find them firmer and harder; befides, if we confider that the Periftaltick Motion is performed by a very fmall Contraction of the Fibres, for which a very fmall Inflation will fuffice; but the Contraction of the Fibres of the Mufcles being great, they muft be confiderably inflated, and confequently more fpongy, and capable of receiving a larger quantity of *Blood*, than the Fibres of the Inteftines; and therefore it is evident, that in the Mufcles which make up far the greateft part of the Body, the Proportion of the *Blood*

to

to the folid Fibres muft be above
3.9 to 1, or almoft as 4 to 1.

To know what Proportion the *Of the*
Fluids of the Nerves bear to the fo- *Quantity*
lid Part of the Nerves. I dried a *in the*
piece of the *Medulla Spinalis* with- *Nerves.*
out any Art or Preparation, excep-
ting the flitting of it, and I found
that it loft near ¾ths of its Weight,
fo that it appears, that even the
Nerves are not more folid than the
other Parts. And as to the Lym-
phatick *Veffels*, I believe every one
will eafily agree, that the Fluids in
them bear a much greater Propor-
tion to their Coats, than what has
yet been found.

The Bones of all the Parts in the *Of the*
Body feem to bid the faireft for *Quantity*
Solidity, and yet even their Fibres *in the*
are not without their circulating *Bones.*
Juices, what elfe is the *Callus* which
unites and cements the Extremities

of

of broken *Bones* ? In it there are no Fibres, nor Parts to be diſtnguiſhed, but it appears like an uniform inſpiſſated Juice. At whatever Time or Age the Misfortune of a broken *Bone* happens, this Juice is always at hand, which ſhews, that it is always circulating, tho' ſlowly : If it ſtagnated, it would harden, as it does when it is extravaſated, and forms a *Callus* ; and conſequently all the Paſſages being obſtructed, no broken *Bone* could unite. This Juice is like to the viſcous Sap of Trees ; for without doubt a Fluid may move as eaſily thro' the Fibres of the *Bones*, as thro' the Fibres of an Oak. The Excreſcencies of the very Subſtance of the *Bones*, their Nodes, Swellings, and ſoftening like Wax, of which there are ſeveral Inſtances to be found in Authors, even of Perſons

fons grown in Years, do fufficient-
ly evince a fluid circulating thro'
their Fibres. No doubt but that
the older we grow, the narrower
are the Channels of the Fibres, the
vifcid Fluid hardening towards their
Sides, and after Death intirely ob-
ftructing them, fo that the whole
Fibre appears folid; but ftill it is
really no part of the Fibre, no more
than the Cruft with which fome
Waters line the Pipes thro' which
they run, is part of the wooden or
leaden Pipe, or the Glew in which
a Sponge has been foaked, can be
faid to be part of the Sponge:
And as thefe may be taken out,
without taking away any of the
Subftance in which they are con-
tained, fo likewife may this Fluid
in the *Bones.* What elfe is the
Jelly made of Harts-horn, but a
Fluid extracted by boiling Water,
<div align="right">the</div>

the Fibres and Subſtance of the Horn ſtill remaining undiſſolved ? Is not the Jelly extorted by *Papin*'s Digeſter out of dry and ſolid *Bones* the ſame Fluid ? That I might know what Proportion it bears to the Fibres of the *Bones*, I cauſed the *Bone* in the Knuckle of Beef, being firſt boiled, and the Marrow taken out, to be put into the Digeſter. Before it was put in, it weighed 22 Ounces 6½ Drachms, when it was taken out and dried, it weighed 11 Ounces 1½ Drachm, ſo that it loſt above half its Weight, and yet the Texture of the ſmalleſt Fibre in the moſt ſpongy Part of the *Bone* was not broken, and the middle or more ſolid Part appeared to be made of Parallel *Laminæ*, of which four or five would hardly exceed the thickneſs of a Sheet of Paper. And I doubt

doubt not but that if the Experiment had been made upon younger *Bones*, but that the Proportion of the Fluids to the folid Part would have been found to be much greater. Now if the *Bones* contain fuch a quantity of Fluid, what do the *Tendons*, *Membranes*, *Ligaments* and *Cartilages*, which are much fofter Subftances, and which upon boiling likewife yield a Jelly? And is not Glew which is extracted out of the Skins of Animals fuch a fort of Fluid? So that it is highly probable, that there is not a Fibre in the whole Body, in which fome Fluid or other does not circulate, but which hardening after Death, and perhaps fome part of it before, no Elixation whatfoever can extract.

Thus have I confider'd the feveral forts of Subftances in the Body, and fhewn what Proportion the Fluids

The Coats of the Veffels compofed of other Veffels.

Fluids in each of them bear at least to their folid Parts, I fay at leaft, for no Preparation nor Art can extract a Fluid fo vifcid, and fo apt to harden, as the *Blood* is, out of the innumerable Meanders of fuch infinitely fmall *Veffels*. I have alfo fuppofed the Coats of the *Veins* and *Arteries* to be perfectly Solid, that is, without Fluids, whereas it is evident to the naked Eye, and agreed on by all *Anatomifts*, that they are compofed of *Myriads* of *Veins* and *Arteries*. What an innumerable company does an Inflammation of the Eye fhew upon the *Tunica Conjunctiva*, and are there not many more to be difcovered by *Microfcopes*, and the finer the Glaffes are which we ufe, ftill the more *Veffels* we difcover, fo that if we can fee no more, it is only becaufe our Glaffes are not better. Who-
foever

foever is acquainted with the Preparations of the curious Dr. *Ruyſck* would be apt to believe that the whole Body, and all its Fibres were nothing but *Blood-Veſſels*.

A piece of the *Aorta* of a Calf weighed 240 Grains, when dried, it weighed 80 Grains; ſo that from this Experiment it appears, that the *Blood* in the Coats of the Arteries is to the Coats as 1.7 to 1, which is the ſame Proportion the *Blood* in the great Arteries bears to their Coats, and yet we cannot ſuppoſe that any more than the thin part of the *Blood* was exhaled. *The quantity of Fluids in the Coats of the Arteries determined by an Experiment.*

Now therefore, ſuppoſing that the *Veſſels* are made up of others, full of Fluids, and that there is the ſame Proportion of the Fluids to the ſolid Parts in each of them, the Quantity of *Blood* in the Body *A general Method to determine the Quantity of Fluids in the Coats of the Veſſels.*

may
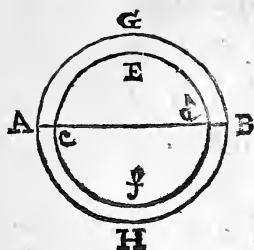
may be thus determined. Let the Annular Space $GABH$, $Ecfd$, be to the whole Circle $AGBH$, as 1 to a; then in a Body composed of such Vessels filled with Fluids, the Fluids will be to the Solids (if the Annular Space is solid) as $a - 1$ to 1. But if this Annular Space is likewise composed of the same sort of Vessels, then in the whole Body the Fluids will be to the Solids as $a^2 - 1$ to 1: and again, if these lesser Vessels are composed of others still less than themselves, then the Fluids will be to the Solids, as $a^3 - 1$ to 1: and if there should be four such Orders of Vessels, the Fluids will be to the Solids, as $a^4 - 1$ to 1: if five, as $a^5 - 1$ to 1: if six, as $a^6 - 1$ to 1: so that the Proportion of the Fluids

to

to the Solids may be increafed in *Infinitum.* In the Arteries *à* is equal to 2.7, in the *Veins* it is equal to 16.6, and according to the feveral Series of *Veffels*, the *Blood* will be to the folid Part of the *Body* in thefe Proportions.

1,7	15,6
6,2	274,5
18,6	4573
52,1 to 1	75932 to 1
142,4	1250492
286,4	20758082

If the *Body* is compofed of *Vef-* *That all* fels, whofe Coats are made of *the Solids* *in an ani-* other *Veffels,* and thefe again of *mal Body* others, as has been faid; then the *at full* *growth* Bodies of the *Animalcula in femine,* *may be no* or the *Prima Stamina vitæ* may be *more than* *what was* increafed to any bulk, and the *in the* Coats of the *Veffels* fo far as we *Animal* *cula in* *femine.* can

can difcern, grow thicker and thicker, without the Addition of any Subftance to the *Veffels*, only by increafing the Quantity of Fluid, with which they are filled. For as the large *Veffels* fwell, fo likewife muft the fmall ones, of which their Coats are compofed down to the very laft, and the fwelling of the feveral Orders of *Veffels* muft neceffarily increafe the thicknefs of the Coat of that *Veffel* which they compofe; fo that by increafing the Number of the Orders of the *Veffels*, the Coats of the firft Order of *Veffels* may be increafed to any Degree, and yet the Diameter of the *Veffels* which compofe thefe Coats, not greater than a given Line.

That the Coats of the great *Veffels* are compofed of fmaller *Veffels*, is Matter of Fact, and we know nothing to the contrary, but

that

that thefe fmall Veffels may be compofed of others ftill fmaller than themfelves. We know not how many *Laminæ* or *Folds* there are in any Membrane of the Body. That excellent Anatomift Mr. *Cowper* informs us, that every Membrane is Veficular, and may be blown into innumerable Cells. That tranfparent Membrane the *Cornea* of the Eye confifts of as many parallel *Laminæ*, as the nicest Hand of the most expert Anatomift can raife. That delicate thin Membrane which involves the *Brain*, divides its felf into two *Laminæ*. And it is very probable, that the *Hydatides*, of which feveral are found within one another, are nothing but the Coats of the Lymphatick Veffels, diftended and feparated by the Lympha, and yet it is hard to conceive any thing thinner than the Coat of a

K   Lym-

Lympheduct, which is not visible
but when it is distended with Lym-
pha. If we know not the Num-
ber of *Laminæ* which compose the
Membranes, how can we reckon
the Number of Fibres, of which the
Laminæ consist? Or how should
we discover the Number of Fibres,
of which each Fibre is made up?
Leeuwenhoeck tells us, That the Fi-
bre of a Muscle which was nine
times smaller than a hair of his
Beard was made up of a hundred
smaller Fibres, and yet each of these
must have had Nerves, Veins and
Arteries, and perhaps each of them
made up of a hundred more: For
of how many Series of Vessels any
one Vessel is made up of, is what
no Microscope can discover; because
only one Order can lie at a time
in the *Focus* of the Glass, and if

more

more could, their feveral Refracti-
ons would confound the Sight.

If all the folid part of the Body *Nutrition*
was contained in the *Animalcule*, *but Diften-*
then *Accretion* and *Nutrition* are no- *tion.*
thing but the Repletion and Di-
ftention of the Veffels, and it is
eafie to conceive how *Helmont*'s
Tree grew from five pound Weight
in five Years time, to one hundred
and fixty nine Pound, only by the
Addition of Water: Nor does this
at all contradict the Ingenious Do-
ctor *Woodward*'s Experiments con-
cerning Vegetation, but his Expe-
riments are rather a Confirmation
of this Doctrine. For the fewer
Terreftrial Particles are contained in
the Water by which any Plant is
nourifhed, the quicker the Water
paffes off thro' the Pores or Excre-
tory Ducts of the Plant, and con-

K 2   fequent-

sequently the less the Vessels are
distended; but if the Water is im-
pregnated with a large quantity of
terrestrial Matter, it cannot pass off
quickly, but being retained in the
Plant, the vessels must be distend-
ed, and consequently the Bulk of
the Plant increased. That the fewer
terrestrial Particles the Water con-
tains, the quicker it passes off, is
evident from Experiments: for
two Plants of Mint, near of the
same Weight, set at the same time,
the one in Rain-Water and the
other in Thames-Water (which is
more copiously stored with terre-
strial Matter) this did thrive to al-
most double the bulk of that, and
with a less Expence of Water;
yet the Experiments do sufficiently
evince, that Plants require a proper
Nourishment, as well as Animals,
without

without which they can never kindly thrive. For Life is continued, and all its Functions performed by the straining off of several sorts of Juices from the common Fluid, which in Animals is called Blood: But if this common Fluid cannot afford these Juices, or is not fit to be turned into them, then that Body whether vegetable or animal, must turn sickly, and at last die. Some sorts of Water are more easily transmuted into the Juices of some Plants than others, for we see some love a very dry and some a very wet Soil, and some will grow in Water alone, and therefore it was that *Helmont*'s Willow Tree grew to such a Bulk.

If the most proper Food can only distend but not increase or add to the Substance of the solid Part of

No equivocal Generation.

K 3 the

the Body, how much more reasonable is it to suppose, that no Matter, howsoever disposed, can at first frame these solid Parts, without an Omnipotent Power immediately actuating it.

The Possibility of the Resurrection of the same Body. And does not all that has been said demonstrate not only the Possibility but likewise the great Probability of that Supposition, which the Reverend and Learned Mr. *Clark* uses to show the Possibility of the Resurrection of the same Body; for if all the solid Parts are no more than the Original *Stamina*, and all Nourishment only a Fluid in a perpetual Flux, then no Part of an animal Body can become Part of another animal Body; but the Body is always the same, from the first Moment of Life to the last.

But

But whether the Coats of the *The Weigh* Veffels are compofed of others, or *of the Fat and Bones* not, the Experiments I have brought *deducted* do clearly demonftrate that the *from the* Fluids in the Body are to the Solids *Quantity of Blood.* at leaft as 3.9 to 1, and therefore in a Body weighing one hundred fixty pound, there muft needs be one hundred twenty feven pound of Blood. From which Quantity that I may put the matter out of all manner of Difpute, I fhall deduct the Weight both of the Fat and Bones, tho' I think that fome Arguments might be alledged to prove that even the Fat circulates, and I have already fhown that there is a Fluid in the Bones.

In a Body weighing one hundred fixty pound, I fhall fuppofe that the Fat is an Inch deep all round the Body, and in fuch a mean Weight, I believe this will be fuf-

ficient

ficient to anſwer for all the Fat every where elſe. Dr. *Wainewright* reckons the Surface of the Body meaſures fifteen ſquare Feet, and therefore the Fat muſt be one hundred eighty cubick Inches. Now a cubick Inch of Fat weighs about half an ounce or ſomething more, and therefore the whole Fat of the Body of a Man weighing one hundred ſixty pound is ninety ounces, or five pound ten ounces; but I ſhall ſuppoſe it to be ſeven, and that the Bones weigh twenty pound, and there remains one hundred pound for the Quantity of Blood in a Man weighing one hundred ſixty Pound.

Concerning the Velocity of the Blood. Having in the firſt Treatiſe ſpoke of the Nature and Quality of the Blood, and in this of its Quantity; it will not be improper in this Place to ſay ſomething

thing concerning its abfolute Ve-
locity.

All who have wrote of the Ve-
locity of the Blood fince the Dif-
covery of its Circulation by the im-
mortal Dr. *Harvey*, have content-
ed themfelves only to calculate the
Quantity which paffes through the
Heart in fome determined Time:
But none has as yet given us the
abfolute Velocity with which it is
thrown out of the Heart, runs
throw the *Aorta*, or any of its
Branches. Many have indeed fpoke
of the rapid Motion of the Blood,
and that it muft be much greater
near the Heart than in the Extre-
mities; but how much greater it is
in that than in thefe, or whether it
moves through the *Aorta* at the rate
of 5, 10, 100, or 1000 Feet in a
Minute, is what has never as yet
been determined; tho' next to the
Circu-

Circulation of the Blood its self, it seems to be a thing of the greatest Moment for explaining of the animal Oeconomy. After the Motion of the Blood was once determined, methinks it was but natural to have enquired in the next Place with what Degree of Velocity it mov'd.

The Velocity of the Blood in the *Aorta* may be thus determined.

The Velocity of the Blood in the Aorta. The Velocity with which a Fluid flows out of any Orifice uniformly and always running in the same Quantity, is equal to the Velocity of a Body which describes a Space of the same length with that of a Cylinder whose Base is equal to the Orifice, and whose Magnitude is equal to the Quantity of the Fluid that runs out in the same time, as 'tis evidently shown in the *Lectiones Physicæ Jo. Keil, pag.* 114. Now suppose

suppose the Heart contracts eighty times in a Minute, and that each Contraction throws into the *Aorta* one Ounce of Blood. An Ounce of Blood is equal in bulk to 1, 659 inch, and consequently 80 Ounces are 132, 72 inches. The Diameter of the *Aorta* in a middle siz'd Man, I have found to be 0, 73 Parts of an Inch, and therefore its Orifice is 0, 4187, by which divide 132, 72, the Quotient 316 inches or 26 feet gives the length of the Cylinder, or the space through which the Blood will go in a Minute, supposing it were constantly going out of the Heart with the same Velocity : But because of the *Diastole* of the Heart, which is at least half the time of a Pulsation, there goes out 80 Ounces in half a Minute, and consequently the Velocity of the Blood is at least twice

as

as great, or such as will make it to move at the rate of 52 Feet in a Minute : I have supposed that the Quantity of Blood that the Heart throws out every *Systole* is only one Ounce; because that (being allowed of by all) gives the least Velocity, and we are sure it is at least so much; but if every *Systole* throws out two Ounces, as many do suppose, then the Velocity is double to what it has been here determined.

If the sum of the Sections of the Branches of the Arteries were always equal to the Section of their Trunks, and if the Circuits in which the Blood moves were every where equal, the Velocity of the Blood would be every where the same it has been determined to be in the *Aorta.* But we find that the sum of the Sections of the Branches do

every

every where exceed the Section of
their Trunks, and therefore the
Velocity of the Blood muft decreafe
as the Number of Branches increafe.
Now let us fuppofe that the fum
of the Sections of the Branches,
bears every where the fame Propor-
tion to their Trunks, and
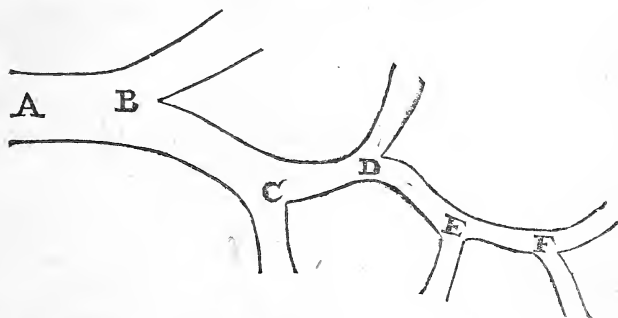
fuppofe A the Trunk of an Artery,
and that at B it divides into two
Branches, and the Branch B like-
wife into two at C, and that a-
gain inro two at D, and fo on :
call A the Section of the Artery,
the fum of the Sections of the
Branches at B call B, and thofe at C

let

let them be named C, and thofe
at D, E and F call alfo D, E and
F. Let the Section of the Canal or
Branch B C, be to the Section of the
two Branches at C, as A is to B. Like-
wife the Section of the Canal C D
to the Section of the two Branches
at D, as A to B, $\mathcal{C}c.$ Then the Ve-
locity at A, will be to the Velocity at
B, as B is to A, and the Velocity at B,
will be to the Velocity at C as B is to
A, and the Velocity at C, will be to
the Velocity at D, as B is to A,
$\mathcal{C}c.$ Let A reprefent the Velo-
city at A, then $\frac{A2}{B}$ will reprefent
the Velocity at B, and $\frac{A3}{B2}$ will be
the Velocity at C; the Velocity at
D will be $\frac{A4}{B3}$, that at E will be $\frac{A5}{B4}$,
that at F will be $\frac{A6}{B5}$: and if the Ar-
tery be divided into a hundred
fuch Branches before it come to the
fmalleft, the Velocity at the laft
of them will be $\frac{A101}{B100}$, if into a thou-
fand

fand, the Velocity at the laft of thefe will be $\frac{A^{1001}}{B^{1000}} = A \times \frac{A^{1000}}{B^{1000}} = $ to the thoufandth Power of $\frac{A}{B}$ multiplied by A: The Velocity therefore at A, is to the Velocity after a thoufand branchings, as A is to A $\times \frac{A^{1000}}{B^{1000}}$, that as is 1 to $\frac{A^{1000}}{B^{1000}}$ or as 1 is to the thoufandth Power of $\frac{A}{B}$.

Thus if the *ratio* of A to B was known, the Velocity of the Blood at the feveral branchings of the Arteries might eafily be determined; but this is only to be found by meafuring of the Arteries, and by the Meafures which I have formerly taken I find the *ratio* in different Places to be very different. I wifh thofe who have more Leifure and Opportunity, would meafure the Circumference of an Artery injected with Wax, both above and below each Divifion, by which means we might come to a greater

Certainty

Certainty in this Matter. The moſt general Proportions of the Trunks to their Branches that I have found are as 41616 to 43506 and as 41616 to 52126: Now if we take the firſt of theſe Proportions, $\frac{A}{B}$ is 0.9565, whoſe Logarithm is 9.9806850: This Logarithm multiplied by 30, gives the Logarithm of the 30th Power of 0.9565 : Now the Logarithm 9.9806850 multiplied by 30 is the Logarithm 9, 4205500, to which the Number anſwering in the Tables is 0.26336. That is the Velocity at A in any Artery, is to the Velocity at the 30th branching as 1 to 0.26336, or as 100-000 is to 26336 which is almoſt as 4 to 1 : The Logarithm of 0.9565 multiplied by 100 gives for the Logarithm of the Velocity at the 100th branching 8.0685000,

the

the Number anfwering to it in the Tables is 0,011708: Hence the Velocity of the Blood in the *Aorta* is to the Velocity in the hundredth Divifion as 1 to 011708, or as 1000 000 to 11708, that is, it will be almoft an hundred times greater. But if we fuppofe that the Artery divides a hundred times before it comes to the fmalleft Capillary or evanefcent Artery. The Logarithm of the thoufanth Power of 0,9565 is 80.6850000 whofe Number is 0,00000 000 000 000 000 000 484, and confequently the Velocity in the *Aorta* will be to the Velocity in its laft branches in a greater Proportion than 10000 000 000 000 000 000 to 1.

If the Proportion between the Trunk of an Artery and its Branches be taken to be as 41616 to 52126,

L   then

then $\frac{A}{?}$ is 0, 7983; and at the hundredth Division the Velocity of the Blood in the Trunk will be to the Velocity in the Branches as 10 000 000000 000 to 16466. At the 200th division as above 10 000 000 000 000 000 000 to 1 : At the 400th it will be as 10000 0000 00000 00000 00000 00000 00000 00000 to 1. Thus having fhewn how the Velocity of the Blood may be determined at each branching of the Artery, our next enquiry muft be to find out how many times an Artery may divide before it becomes the fmalleft Capillary, which may be thus done.

Suppofe the *ratio* of the Trunk to the Branches to be as r : s. and call the Trunk c, then $r : s :: c : \frac{sc}{r}$ which is therefore the fum of the two firft Branches, and each Branch is $\frac{sc}{2r}$, again $r : s :: \frac{sc}{2r} : \frac{s^2c}{2r^2}$ this is the

fum

fum of the fecond branching, of which $\frac{1}{2}$ is the Branch $=\frac{s^2c}{4r^2}$, and juft fo the third Branch will be $=\frac{s^3c}{8r^3}=$ to the Cube of $\frac{s}{2r}$ multiplied by c.

Now if we call the number of branchings x, and $\frac{s}{2r}=d$, the laft Branch will be $d^x c$. Let us fuppofe the fmalleft Artery has its Diameter $\frac{1}{100}$ part of a Hair's Breadth, and that the Diameter of a Hair is the $\frac{1}{200}$ part of an Inch, the Section of this Artery will be 0,000 000 00 25, which I fhall call $=$ e. Then we have this Equation $d^x c = e$, which expreffed by Logarithms is $x \times$ Log. $d +$ Log. $c =$ Log. e, and $\frac{\text{Log. } e - \text{Log. } c}{\text{Log. } d} = x$.

Let us take the Proportion between the Trunk and the Branches to be as 41616 to 43506 $:: r : s$, then the Logarithm of s divided by 2r is $-$ 0.2817412 $=$ Loga-

L 2   rithm

rithm of d, it being equal to the Logarithm of s *minus* the Logarithm of 2r : The Logarithm of e is — 8.6020600, and supposing c equal to the Diameter of the *Aorta* equal to 0,5329 Decimals of an Inch, its Logarithm is---0.2733543, and the Logarithm of e *minus* the Logarithm of c is — 8,3287057, this divided by — 0,2817412 gives in the Quotient something less than 20 for the Number of branchings between the *Aorta* and the smallest Capillary, and consequently the Velocity of the Blood in the *Aorta* is about four times greater than it is in the last Division of the Artery.

But this number of branchings is undoubtedly too few, if we consider the number of Arteries it produces for the whole Body.
For

For at F the number of Branches
are 2, at E 4, at D 8, at C 16,
at B 32, and therefore at 30 the
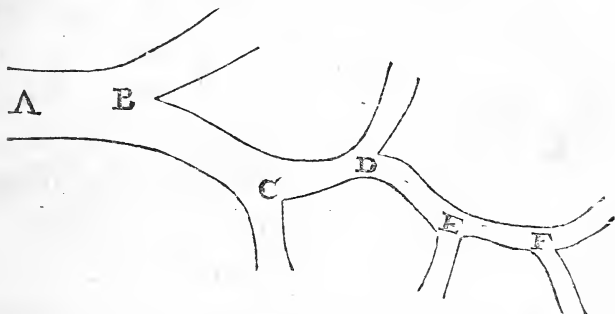
number of Arteries in the whole
Body will be the 30th Power of 2
which is 1073 000 000, a number
which muſt be prodigiouſly ſhort
of the true number, if we conſider
that every Fibre of a Muſcle, and
every Veſicle of a Fibre is nothing
but a Net-work of Blood Veſſels.
The *ratio* therefore of the Branches
to their Trunks muſt be much great-
er than 41616 to 43506, and in
fact we do frequently find it great-
er. Let us therefore ſee what the
number

number of Branchings will be from the other *ratio* of 41616 to 52126, which is almost as frequent as the first, especially at some distance from the *Aorta*: Then 41616 is to 52126 :: r : s. and the Logarithm of s *minus* the Logarithm of 2r is — 0.203237 = Logarithm of d, by which number if we divide — 8.3287057 = Logarithm of e — Logarithm of c, the Quotient gives for the number of branchings above 400 and consequently the greatest Velocity of the Blood will be to the least in a greater Proportion than 1.000 00000 00000 00000 00000 00000 00000 00000 to 1.

Thus we see how prodigiously the Velocity of the Blood decreases as the number of branchings encrease ; and tho' perhaps we have not taken the exactest *ratio* of the Branches

Branches to their Trunks; yet whenever that shall be known, the Method we have here used, is that whereby the Velocities at the several branchings may be determined. This much I am assured of, the last *ratio* of the Branches to their Trunks falls much short of what I have found in several Places of the Body, and I am apt to think that the *ratio* encreases every Division from the great Arteries. Some nice and exact Measures of the *Vessels* taken after the manner I have proposed would give us a certain Knowledge of this part of the animal Oeconomy.

But till this exact *ratio* is discovered, let us suppose the least Velocity to be as we have calculated it at the hundredth Division only that is 100000000 times less than it is in the *Aorta*; then when

L 4 the

the Blood in the laſt Diviſion of the Artery moves one Foot, that in the *Aorta* moves 1000000000; now the Blood in the *Aorta* moves at the rate of 52 Feet in a Minute, and conſequently it moves 100000000 Feet in 13354 Days, in which time the Blood at the hundreth Diviſion moves only one Foot, or it would be 278 Days in moving of a Quarter of an Inch, if the laſt Branches were ſo long: But if the leaſt Velocity is at the ſeventieth Diviſion, the Blood will move there at the rate of a Foot in about thirteen Days: And at the fiftieth at the rate of a Foot in three Hours.

As between the greateſt and the leaſt Velocity we are to conceive all the intermediate Degrees; ſo we are not to imagine that in every evaneſcent Artery there is the leaſt Velocity, but only in ſuch as have an hundred
dred

dred Divifions between them and the great Artery, and the Velocity of the Blood in the evanefcent Arteries is every where proportionable to the number of Divifions between them and the great Artery; and therefore in all the fmall Arteries which come immediately from the *Aorta*, and which after a few Divifions tranfmit their Fluid to the Veins, the Velocity of the Blood is but a little diminifhed.

From all this it appears that when the whole Mafs of Blood is to be altered, that the Courfe of Phyfick ought to be continued for a long Space of time, being the Blood moves flower and flower the farther it moves from a great Artery, and confequently it muft be a great time before the whole Mafs of Blood can be mixt with the alterative Medicine. And being the

Circu-

Circulation of the Blood through
Glands which receive Arteries im-
mediately from a great Veffel, is
very quick, they may carry off a
great Proportion of the Medicine in
a very little time, and therefore it
is not the taking of great Quanti-
ties, but a conftant taking that can
alter the Mafs of Blood; and from
hence it follows that when the Blood
is to be altered by mineral Waters,
which are apt to pafs through the
Glands of the Kidneys, that they
ought not to be drunk in large
Quantities: For if they pafs off,
they have not the defigned Effect;
and if they do not, being drunk
in a little time, they mix but with
a fmall Quantity of Blood, which
muft diforder the animal Oeconomy.

Of Muscular Motion.

A Muscle is a Bundle of thin and parallel Plates of flefhy Threads or Fibres, enclofed by one common Membrane: All the Fibres of the fame Plate are parallel to one another, and tied together at extremely little diftances, by fhort and tranfverfe Fibres. The flefhy Fibres are compofed of other fmaller Fibres enclofed likewife by a common Membrane: Each leffer Fibre confifts of very fmall *Vesicles* or Bladders into which we fuppofe the Nerves, Veins and Arteries to open; for every Mufcle receives Branches of all thofe *Vessels*, which muft be diftributed to every Fibre. The two Ends of each Mufcle, or the Extremities of the Fibres, are

in

in the Limbs of Animals fasten-
ed to two *Bones*, the one movea-
ble, the other fixt, and therefore
when the Muscles contract, they
draw the moveable *Bone* according
to the Direction of their Fibres.
When the Muscles contract in
length, they swell in thickness, as
may be perceived by laying the
Hand upon the *Masseter* a Muscle
of the lower Jaw, and pressing the
Grinders together: but this Power
of contracting or swelling is lost
when either the Artery or Nerve
of the Muscle is cut or tied, and
therefore we conclude that the Con-
traction, Swelling, or Motion of the
Muscles is performed by the *Blood*
and *Animal Spirits* distending the
Vesicles or Cavities of the Fibres.
This Distention of the *Vesicles* of
the Fibres must be either by their
being filled with a greater Quantity
of

of *Blood* and animal Spirits than they were before the Contraction, or the *Blood* and Spirits mixing muft rarifie, and fill up a greater fpace.

That the *Veficles* of the Fibres are not diftended purely by the Quantity of *Blood* and Spirits will appear if we confider, that were the *Veficles* diftended only by the Quantity of Fluids contained in them, Nature (whofe Operations are always the moft fimple) had only ufed one Fluid and not two; for in the Works of Nature we no where find two neceffary Caufes where one could have produced the fame Effect: Now how fmall foever we fuppofe the Quantity of Fluid brought by the Nerves to the Mufcles, that alone might have contracted the Fibres (if a Quantity only of a Fluid had been requifite)

by

by dimishing the Diameters of the Cavities or *Vesicles* of the Fibres, as will appear by the sequel of this Discourse. And as it is evident that the reason why the Spirits alone do not distend the *Vesicles*, is not that there is not a sufficient Quantity for that purpose; so it will likewise appear that if there had not been a sufficient Quantity of the nervous Fluid, yet the Quantity of Blood could have given no assistance in the Distention of the *Vesicles*; for if the *Vesicles* contain a greater Quantity of *Blood* when the Muscles contract, than they do when the Muscles are relaxed, this Augmentation must proceed either from the *Bloods* being stop'd in the *Vein*, or it must move suddenly with a greater *Velocity* thro' the Artery into the Cavities of the Fibres. If the *Blood* is stopp'd in the

the *Vein*, it muſt be by the Con-
traction of its Coats, or by ſome
external Preſſure upon them : If by
the Contraction of the Fibres which
compoſe the Coats of the *Vein*, the
ſame difficulty remains to be ex-
plained, for whatever is the cauſe
of the Contraction of the Fibres of
a *Vein*, will likewiſe ſerve to con-
tract the Fibres of a *Muſcle*. If
the *Blood* is ſtopp'd in the *Veins* by
a preſſure upon their Coats, it muſt
be by the ſwelling of the Artery
or Muſcular Fibres. If the Artery
ſwells and preſſes on the *Vein*, the
Circulation of the *Blood* muſt be
intirely ſtopp'd; for that Preſſure
will conſtantly encreaſe, the *Blood*
being ſtill accumulated in the Arte-
ry, and therefore it will for ever hin-
der all Paſſage through the *Vein* :
If it be ſaid that the *Blood* moving
ſometimes with a greater *Velocity*
through

through the Artery into the Cells or *Vesicles* of the Fibres, will distend them ; this greater *Velocity* must proceed from the force of the Heart, from which alone the *Blood* derives all its Motion : Now if the Heart acts with a greater force it will encrease the *Velocity* of the *Blood* universally throughout the whole *Body*, and each Muscle and its Antagonist will be thereby equally contracted, and consequently neither will contract. And therefore being both the *Blood* and Fluid of the Nerves are necessary to the Contraction of the Muscles, and being the Contraction is not performed by the Quantity of these Fluids, it remains only that by their Mixture, they rarifie and distend *Vesicles*.

Now for the explaining of this Rarifaction of the *Blood* and Spi-

rits

rits in the *Vesicles* of the muscular
Fibres, let us suppose a small Glo-
bule of Air between the Particles
of a Fluid, and that the Particles
have a strong attractive force by
which they endeavour to come to-
gether, they pressing every way e-
qually on the Globule of the Air,
will hinder it from escaping any
way from between them; but the
force by which they endeavour to
come together, being prodigiously
greater than the force of their Gra-
vity, they will by this force produce
a very considerable Condensation
of the Globule of Air that lies be-
tween them, and the force of Ela-
sticity being proportional always
to its Condensation, the force by
which this airy Globule will endea-
vour to expand its self, will like-
wise be vastly great; and conse-
quently if by any means this *Nisus*

of

of the Particles of the Fluid to come together should be taken off, the Air between them would expand its self with a very considerable force. Now if upon the mixing of another Fluid the Particles of the first Fluid should be more strongly attracted to the Particles of this other Fluid, than they were before to one another, then would their *Nisus* to one another cease; and they would give the Globule of Air that is between them, liberty immediately to expand it self; and the whole Fluid would take up a greater space than it did before. But when the Particles of the two Fluids come to be united together, they will again enclose the Globule of Air that lies between them, and by their mutual Attraction soon bring it to its former State of Condensation.

Now

Now that the *Blood* contains a great number of Globules of Air is evident from the Quantity it yeilds in the Air Pump. And that the Particles of the *Blood* have a strong attractive force is likewise plain from what has been said in the Theory of Secretion. By this Attraction of the Particles, the Globules of the *Blood* are formed; and in viewing the Circulation of the *Blood* with a Microscope, I have sometimes observed, that where the Diameter of the Canal has been less than the Diameter of a Globule of *Blood*, that the Globule would be pressed into a Spheroidical Form, but when it came into a wider part of the Canal again it would immediately reassume its former Figure; which I think is probably owing to a smaller Globule of Air enclosed within, and expand-

M 2   ing

ing its ſelf equally every way, when
the ſides of its circumambient Shell
of *Blood*, are not longer preſſed by
the ſides of the Canal.

These Globules of *Blood* continu-
ally circulating through the *Veſicles*
of the Fibres (which are probably
capable of containing only one Glo-
bule at a time) meet with the Ani-
mal Spirits, which drop from the
Nerves. Now the Minuteneſs of the
Glands of the Brain, and the Smal-
neſs of the Fibres of the *Nerves*,
plainly ſhow that the *Animal Spi-
rits* are a Fluid, conſiſting of the
ſmalleſt Particles of any in the Bo-
dy ; and therefore their attractive
Force muſt be the greateſt of all the
Particles in the Blood, as is evident
from what Sir *I. Newton* has calcu-
lated about the Rays of Light ; and
conſequently the *Animal Spirits*
meeting with the *Globules* of the
Blood

Blood in the *Vesicles* of the Fibres, and surrounding them, must attract the Particles of which they are composed, more strongly than they do another; and consequently their *Nisus* to one another ceasing, the condensed Globule of Air will expand its self with a very considerable force, whereby each *Vesicle* of the Fibre will be distended, and consequently the Fibre shortned, *i. e.* the whole Muscle will be contracted. But when the Particles of the Globule of *Blood* are mixed with the nervous Fluid, they will both together enclose the Globule of Air again and compress it into as small a space as it was before, and thus the Contraction of the Muscle must immediately cease; unless fresh Blood and Spirits still succeeding one another continue the Inflation of the *Vesicles.* But when a Muscle

M 3   has

has been strongly contracted for some time, the Quantity of Spirits spent, being more than can be secerned in the same space of time by the Glands which supply its Nerves, the Inflation of the *Vesicles* must fall, and the Muscle grow feeble and weak; whereas the Tonick Motion of the Muscles, being performed by the Spirits protruded only by the Quantity last secerned in the Glands, will constantly continue without any weariness.

After this manner I conceive the *Vesicles* to be distended without any Ebullition or Effervescence, and their Distention to cease without any Precipitation, or flying off of the aerial Globules through the Pores of the Muscles. For to this Attraction of the Particles of Matter is owing most of the *Phænomena*; for explaining of which, Philosophers have been

4

been forced to have recourse to a-
ctive and subtile Particles, which
contrary to their own Principles
they have made to move themselves
every way, and to do what ever they
had a mind should be done : But
how these Particles came by so great
an Activity was not at all to be ac-
counted for from any of their Prin-
ciples.   Thus in explaining of Mus-
cular Motion they make the animal
Spirits to cut and pierce the Glo-
bules of Blood, and with their sharp
Points to run them through and
through, that the imprison'd Ela-
stick *Aura* might be set at liberty ;
which notwithstanding could not
be effected, unless we suppose that
Holes may be made in Fluid Glo-
bules, as in a Board, and that the
Fluid Particles stand in a Heap, as
the Waters of the Red Sea did.
And when the Aerial Globule is

got loose, the Intumescence of the *Vesicle* cannot be asswaged, but by supposing the Elastick Globules now to have Strength to break through the Muscles and Skin to come at the external Air, tho' before they had not Power nor Subtilty enough to get through a thin Shell of Blood.

But I come now to show the Mechanism of the Fibres, or how excellently and wisely they are contrived for contraction : It is a known Experiment that a Bladder when it is blown up and distended as to its Capacity, but contracted as to its length, will by the force of Contraction, raise a Weight to some determined height. And if two Bladders joined together and communicating with one another were blown up, the Weight would be raised by Inflation twice the

space

space that one alone would do it ; because I suppose that both Bladders contract equally , and consequently the Contraction of both together will be double the Contraction of either. Three Bladders thus joined and distended will raise the Weight to triple the Height , and four to quadruple ; so that if there were a String of Bladders join'd together , of equal Bulk, and like Figures, the space through which the Weight wou'd rise, wou'd be proportional to the number of Bladders, or, which is the same thing, to the length of the String.

Each Fibre of a Muscle consisting of a Multitude of small *Vesicles*, resembles a string of Bladders ; and therefore the Contraction of the Muscle, is always proportional to the length of its Fibres. And being

ing

ing the greatest Contraction of the
Fibres is always less than $\frac{1}{7}$ of their
length (as shall hereafter be demon-
strated) there was a necessity that
the Insertions of the Muscles should
be near to the Joints, not only to
encrease the Velocity of the Parts
moved ; but likewise that they
might describe greater Arches round
the Centers of their Motion : And
hence it is that those Parts which
describe the greatest Arches, are
moved by the longest Muscles ; as
the Hand round the Elbow which
is bent by the *Biceps* arising from
the *Scapula,* and the Foot round
the Knee which is bent by the
Muscles whose Originations are as
far distant as the *Ischium.* If these
Joints had been moved by short
Muscles inserted at each end into
the Extremities of the articulated
Bones, the Arm and Leg had mo-
ved

ved but a little way, and the
Arches the Hand and Foot had de-
scribed about these Joints, had
been to the Arches they describe
now, as the length of the short
Muscles had been to the length of
the Muscles they have now. On
the contrary, where the Joints have
but a small Motion there the
Muscles are short; thus we find
that the Fingers are pulled side-
ways by the *Interossei*, the Thigh is
drawn outwards, and obliquely by
the *Quadrigemini* and *Obturatores*,
which are all short Muscles, and
most of the Muscles of the *Verte-
bræ* run between one *Vertebra* and
the next. From hence it is evident
that the Originations and Insertions
of the Muscles, are every where the
best that could be contrived.

The Vesicles of which the Fibres
consist are extremely small, for tho'
one

one large Bladder may raife a Weight
as high as feveral fmall ones, yet
the Quantity of Elaftick Fluid ufed
in the Inflation together, with the
fwelling of the large Bladder, will
be much greater, than when a
Weight is raifed by a ftring of
fmall ones. For fuppofe two Blad-
ders of fimilar Figures, but the Di-
ameter of the one triple of the Di-
ameter of the other, then will the
one require twenty feven times the
Quantity of Elaftick Fluid to ex-
pand it that the other does, and
it will fwell to twenty feven
times the fpace; and yet three
of the leffer Bladders joined to-
gether will raife the Weight to
the fame Height that the bigger
one does, but with nine times lefs
Expence of Elaftick Fluid, and
they will take up but one ninth
Part of the fpace. By diminifhing
there-

therefore the Bignefs of the Veficles, and encreafing their Number, the force required to diftend the Veficles, and the Diftention its felf may be diminifhed in any given Proportion, and come at laft to be infenfible. Suppofe a Bladder of a determined Bignefs can raife a Weight a Foot; a hundred Bladders whofe Diameters are each $\frac{1}{100}$ part of the former being blown up will raife the Weight to the fame Height, but the force of Inflation and the fwelling of all put together will be ten thoufand times lefs than in the large one.

If a Weight of a determined Bignefs can be raifed to a certain Height by one Bladder, or one String of Bladders to which the Weight is tyed; twice that Weight may be raifed by two fuch Bladders, or Strings of Bladders, and

triple

triple that Weight by three such
Strings. And consequently the
Weight a Muscle can raise, will
be always as the Number of its
Fibres, that is, as its Thickness sup-
posing the Distention of the Vesi-
cles equal. And the absolute
Strength of one Muscle is to the
absolute Strength of another, as
their Bulks.

It is to be observed that in de-
termining both the Contraction and
Strength of a Muscle, no regard is
to be had to the Tendons; because
in them we observe no Inflation,
and we find nature no where mak-
ing use of a Tendon, but where
either there was not room for the
Insertion of so many fleshy Fibres,
or where it was necessary the Muscle
should draw from such a Point.

I shall in the next Place determine
the force of the Elastick Fluid ne-
cessary

ceſſary to diſtend the Veſicles ſo
as to raiſe to a determined Height
any given Weight. But before this
can be done, the Figure that each
Veſicle will be formed into by
the force of the Elaſtick Fluid di-
ſtending it, muſt be found out;
And therefore let us conceive each
Veſicle to conſiſt of an infinite
number of Threads, whoſe Ends
are faſtened by tranſverſe Liga-
ments; and from hence it follows
that if a diſtended Veſicle were cut
with a Plane thro' its Axis, the
Curve of the Section will be the
ſame with that of a Thread whoſe
two Ends are faſtened, and the
whole preſſed by an Elaſtick Fluid;
and becauſe Elaſtick Fluids endea-
vour to expand themſelves every
way, and all Fluids preſs perpendi-
cularly on each Obſtacle, it is evi-
dent

dent that the Thread must be every where equally and perpendicularly pressed, and therefore its Flexion or Curvature must be every where equal and similar, and consequently the Thread must be formed into a circular Arch. Hence it follows that the whole Secretion of the Vesicle consists of two equal and similar Arches, whose common Subtense is the Axis of the Vesicle. Suppose now A E B and A D B to be the two circular Arches, C the Center of the Arch A E B, A G and B F Tangents in the Points A and B, Z the resistance to be raised. The Angle CAG or CAE is equal to a right Angle = to C A R + A C R, and therefore the Angle A C R = G A R, or E A R = E B R = D B R and therefore the Arch E A or E B is the Measure of the Angle E A R, or

or E B R, and the Space through which the Reſiſtance Z is raiſed is equal to the difference between the Arch AEB and its Chord ARB, or equal to twice the Difference of the Arch A E and its Sine A R, which having the Arch A E or the Angle E A R given in Degrees and Minutes may be eaſily calculated. But to do this the Length of the Radius A C muſt be determined in ſuch Parts, wherof 100000 make up the Arch A E which is done thus. The Degrees of a circular Arch, whoſe Length is equal to the Radius of the Circle is 57° 295 and therefore the Degrees in the Arch

N AE is
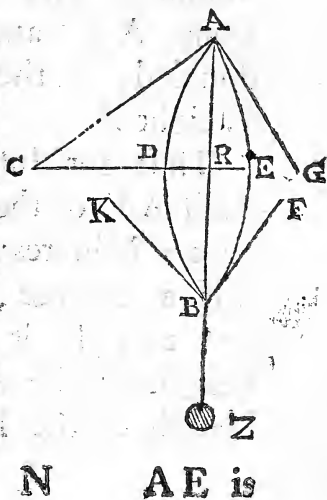
A E is to 57° 295 the Length of the Radius expreſſed in Degrees as 100000, the Parts of which the Arch A E conſiſts, to the Radius expreſſed in the ſame Parts, which will therefore be given. And again, as the Tabular Radius is to the Tabular Sine of the Arch A E, ſo is the Radius A C (which is already found) to the Sine A R which will likewiſe be found. This being ſubſtracted from A E and the Remainder doubled, is the Elevation of the Weight Z.

Thus for Inſtance ſuppoſe the Arch A E or the Angle E B R to be 30 Minutes, ſay as 30′, or half a Degree, that is ÷ is to 57° 295 ſo it is 100000 the Length of the Arch A E, to the Length of the Radius A C which

<div align="right">will</div>

will be found to be 11459000.
And again as 100000 is to 872
the Sine of 30′ ſo is 11459000
to A R which is therefore 99906,
which ſubſtracted from A E, and
the Remainder doubled, gives 186
the Sublevation of the Weight
Z in ſuch Parts whereof A E is
100000.

The Tenſion of the Fibre or the
Force wherewith it is ſttretch'd by
the Reſiſtance Z may be thus de-
termined. The Tenſion of the Fi-
bre, or the Force ſuſtaining the
Weight in the Point B, is the ſame
as if the Weight Z were ſuſpend-
ed by two Threads touching the
Arches in the Point B, and in that
Caſe the Tenſion of the Thread
B F is to the Weight Z as the Sine
of the Angle F B R or E B R is to
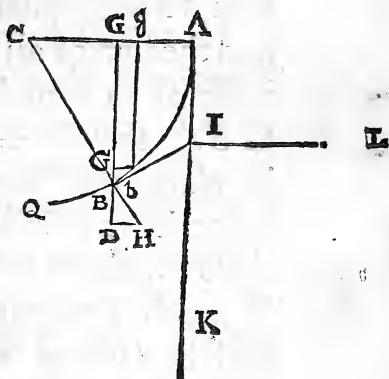the Sine of the Angle F B H or
E B D

E B D (a) and consequently the Tension or Firmness of the Thread will be $= \frac{Z \times \text{Sine E B R}}{\text{Sine E B D}}.$

Now call the absolute force of Expansion that the Elastick Fluid must have to raise a given Weight to a determined Height n; the Pressure on any Part of the Thread will be as the Force of Expansion of the Fluid, and the Portion conjunctly; for if the Portions of the Thread be taken equal, the Pressures on them will be as the Force of Expansion, or the Elasticity, and if the Force of Expansion be the same, the Pressure is as the Portions on which it presses; and therefore universally it is as the Force of Expansion, and the Portion jointly, or as the Product of the two.

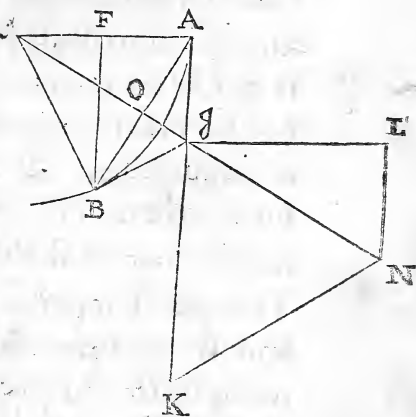*(a)* By the 2d cor. prop. 33 of the Lectiones Physicæ Jo Keil.

Let

Let A B represent the circulare
Thread, B b an indefinite small
Portion of the
same, and the
Pressure on B b
will be n x B b,
which suppose e-
qual to B H: The
Pressure B H can
be resolved into
two Forces, one
whereof is as D H
acting horizontally, or according to
the Direction D H, and the other
at B D acting vertically, or accor-
ding to the vertical Direction B D,
and because of the equiangular Tri-
angles G B b and B D H. B G :
D H :: B b : B H :: B b : n x B b
(:: 1 : n) :: G b : B D, there-
fore D H = n B G, and B D =
n G b, and therefore the sum of all
the

the horizontal Forces will be equal
to n multiplied by all the B G's,
that is n multiplied by B F = n × B F,
and the ſum of all the vertical Forces
is equal to n multiplied by all the
G b's, that is = n A F. Now it
is plain that the Tenſion of the
Fibre in the Points A and B is the
ſame with the Tenſion of two
Threads Tangents in the Points A
and B (where they are ſuppoſed
to be faſtened) that are drawn at
their Point of Concourſe I by all the
horizontal Forces according to the
Direction I L, and by all the ver-
tical Forces according to the Dire-
ction I K: and therefore to deter-
mine the Tenſion of the Fibre, the
Tenſion muſt be determined of the
Threads that are pulled at the Point
I by a Force n F B according to
the Direction I L, and by a Force
n F A

n F A according to the Direction
I K. Take I L = n F B and L N
perpendicular
to it = n F A,
and the two
Forces I L and
L N will be e-
quipollent to a
third Force as
I N acting ac-
cording to the
Direction I N ,
and therefore
the Threads will be ſtretch'd to the
ſame Degree by the Force I N that
they would be by the two Forces
I L and L N , and becauſe I L
(n B F) : L N (n F A) : : B F :
F A, and the Angles at L and F
equal (by the 6th of the 6th) the
Triangles B F A and I L N will be
equiangular, and the Side I N will
be

be equal to n B A, and the Angle
F A B $=$ L N I $=$ (by 29. 1) A I O,
add the Angle I A O to both, and
the right Angle F A I will be equal
to A I O $+$ I A O $=$ (32. 1) A O C;
and therefore because A I $=$ I B,
and the Angles at A and B equal,
the Angle A I O must be $=$ B I O
and A O $=$ O B the Line therefore
N O cutting the Line A B equal-
ly and at right Angles must pass
through the Center. Through N
draw N K parallel to B I, meeting
with A I produced in the Point K,
then the Forces by which the
Threads are stretched will be as I K
and N K, (*a*) the Angle K I N $=$
A I O $=$ F A B $=$ B I O $=$ I N K.
The Triangle therefore K I N is an
Isosceles Triangle, and equiangular

(*a*) Keils Lectiones Physicæ *prop.* 33.

to the Triangle A B C, and A B
: A C :: N I : I K :: n A B :
n A C and thererefore I K or K N
will be equal to n x A C, that is
the Forces by which the Threads
are ftretch'd will be equal to the
Radius of the Circle multiplied
by n.

Hence the Tenfion of the Fibre
in the Points A and B, and fo in
all other of its Parts, is the fame
and equal to the abfolute Force of
Elafticity multiplied into the Radi-
us of the Circle. But the Tenfion
of the Fibre was found before to
be $\frac{Z \times Sin\ EBR}{Sin\ EBD}$, therefore if we call the
Radius r. $nr = \frac{Z \times Sin\ EBR}{Sin\ EBD}$ and $n = \frac{Z \times Sin\ EBR}{r \times Sin\ EBD}$ and r x Sin E B D will
have the fame Proportion to the
Sine E B R as Z to n. Hence is is
plain that no finite Force of Elafti-
city can extend the Fibre A E B D

O   to

to a complete Circle, for in that
case the Sine of the Angle E B D
being nothing r x Sin E B D is no-
thing, and therefore Z will be to n
as nothing to something, or as a fi-
nite to an infinite.

The greatest Contraction of the
Fibre that can be, must always be
less than 72728 of such Parts where-
of the Arch A E, is 100000, for
if the Threads were extended into
complete Circles, the Contracti-
on would be only $\frac{72728}{100000}$ of A E,
which it can never arrive to; there-
fore the Contraction must be al-
ways less than $\frac{3}{4}$ of the Length of
the Fibre : It is also plain that
when the Angle E B R is small, the
Force of Elasticity bears but a small
Proportion to the Resistance. For
Example when the Angle E B R is
but 30′ the Radius or r multiplied

into

into the Sine of the Angle E B D the Sine of one Degree, is to the Sine of the Angle E B R the Sine of 30' as Z to n, that is, r x 1745 : 872 :: Z : n, that is Z : n :: 11459 000 x 1745 : 872 :: 1999-5955000 : 872 :: 22931141 : 1, and consequently a small Degree of Elasticity will produce a prodigious Energy in the Muscles.

F I N I S.

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